EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Blakeney (Norfolk)

2010

Cover photo: Wells-next-the-Sea Channel.

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STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc production areas in Blakeney (Norfolk). Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, as determined in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

DISSEMINATION STATUS: Food Standards Agency, Environment Agency, North Norfolk District Council, Eastern Sea Fisheries Joint Committee.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2010. Sanitary Survey of Blakeney (Norfolk). Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under Regulation (EC) No. 854/2004.

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Acknowledgements

1 INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

Filter feeding, bivalve molluscan shellfish (e.g. cockles, mussels) retain and accumulate a variety of microorganisms from their natural environments. Since filter feeding promotes retention and accumulation of these microorganisms, the microbiological safety of bivalves for human consumption depends heavily on the quality of the waters from which they are taken (Bell, 2006).

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. Infectious disease outbreaks are more likely to occur in coastal areas, where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and /or animal origin.

In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007).

The risk of contamination of bivalve molluscs with pathogens is assessed through the microbiological monitoring of bivalves. This assessment results in the classification of BMPAs, which determines the level of treatment (e.g. purification, relaying, cooking) required before human consumption of bivalves (Lee and Younger, 2002).

Under EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of BMPAs and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The Centre for Environment Fisheries & Aquaculture Science (Cefas) is performing sanitary surveys for new BMPAs in England and Wales, on behalf of the Food Standards Agency (FSA). The purposes of the sanitary surveys are to demonstrate compliance with the requirements stated in Annex II (Chapter II paragraph 6) of EC Regulation 854/2004, whereby 'if the competent authority decides in principle to classify a production or relay area it must:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;

(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;

(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; and

(d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.'

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as an indicator of microbiological contamination in bivalves. This bacterium is present in animal and human faeces in large numbers and is therefore indicative of contamination of faecal origin.

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and better analyse their effects on BMPAs. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents information relevant to undertake a sanitary survey for a new bed for wild mussels (*Mytilus* spp.) in Wells-next-the-Sea Harbour (Wells Harbour) and existing classified beds for farmed mussels and farmed Pacific oysters in Blakeney BMPA area.

1.2 Site Description

CENTRAL NORFOLK COAST AND STIFFKEY ESTUARY

The bivalve mollusc production area (BMPA) assessed for the purposes of this sanitary survey (Blakeney) includes classified beds situated along the stretch of coast from East of Holkham Bay to Blakeney Harbour, in the central part of the Norfolk Coast, on the east coast of England (Figure 1.1).

The North Norfolk coast is one of the largest expanses of undeveloped coastline in Europe, providing habitat for rare plants and animals (Spiller, 2005). This stretch of coast is characterised by a barrier beach system, where extensive areas of saltmarsh have been maintained behind a protective barrier of sand and shingle bars. The open coast is characterised by large areas of mobile sand subject to marine conditions. It includes Wells Harbour (Figure 1.1), the largest of five tidal deltas along the North Norfolk coast, which comprise extensive sand waves and sandflats and Blakeney Spit Pools, a small percolating coastal lagoon made up of six small pools of shingle overlaid by soft mud between the shingle ridge and the saltmarsh (Figure 1.2).

The urbanised area of Wells-next-the-Sea is protected by a seawall.

Table 1.1 summarises the main characteristics along the North Norfolk coast.

Table 1.1. Main characteristics of the North Norfolk Coast.

Geomorphological classification	Barrier beach system, tidal inlet
Shoreline length (km)	70
Core area (ha)	6,292
Intertidal area (ha)	5,874

Data from The Estuary Guide (ABPmer and Wallingford, 2009)

The saltmarsh area from Wells-next-the-Sea to Blakeney extends for approximately 1,052 ha (Boorman, 2003). Saltmarsh contributes significantly to pollution control and water quality through nutrient cycling (e.g. nitrogen and phosphorous release during decomposition of organic matter) and sediment retention (e.g. adsorption of pollutants onto sediment particles) (Adnitt *et al*., in press).

Commercial uses of Wells Harbour include fisheries and tourism. Tourism-related activities are both water-based (e.g. boating, fishing, canoeing) and land-based (e.g. walking, bird-watching, cultural).

Figure 1.1 Aerial view of Wells Harbour (B).
Reproduced under licence Google Earth™ mapping service.

Figure 1.2 Aerial view of Blakeney lagoon. *Reproduced under licence Google Earth™ mapping service.*

CATCHMENT CHARACTERISATION

The BMPA is under the influence of pollution sources from sub-catchments shown in Figure 1.3. These catchments are essentially rural in character.

Catchment topography comprises mainly flat land with gentle gradients through the catchment to sea level. The elevation in the Stiffkey river catchment ranges between 0−100m (weighted average=50.2 m). Approximately 73% of the Stiffkey river catchment is above 60m elevation (NERC, 2005).

Arable land comprises approximately 78% of the Stiffkey river catchment (NERC, 2005).

Flat land is expected to generate lower volumes of surface runoff and potentially microbiological contamination of faecal origin than those volumes in steep-sided catchments in other parts of England and Wales.

The geology of these catchments comprises mainly of chalk with 75% boulder clay cover with high permeability covering the whole catchment (Pethick and Cottle, 2003).

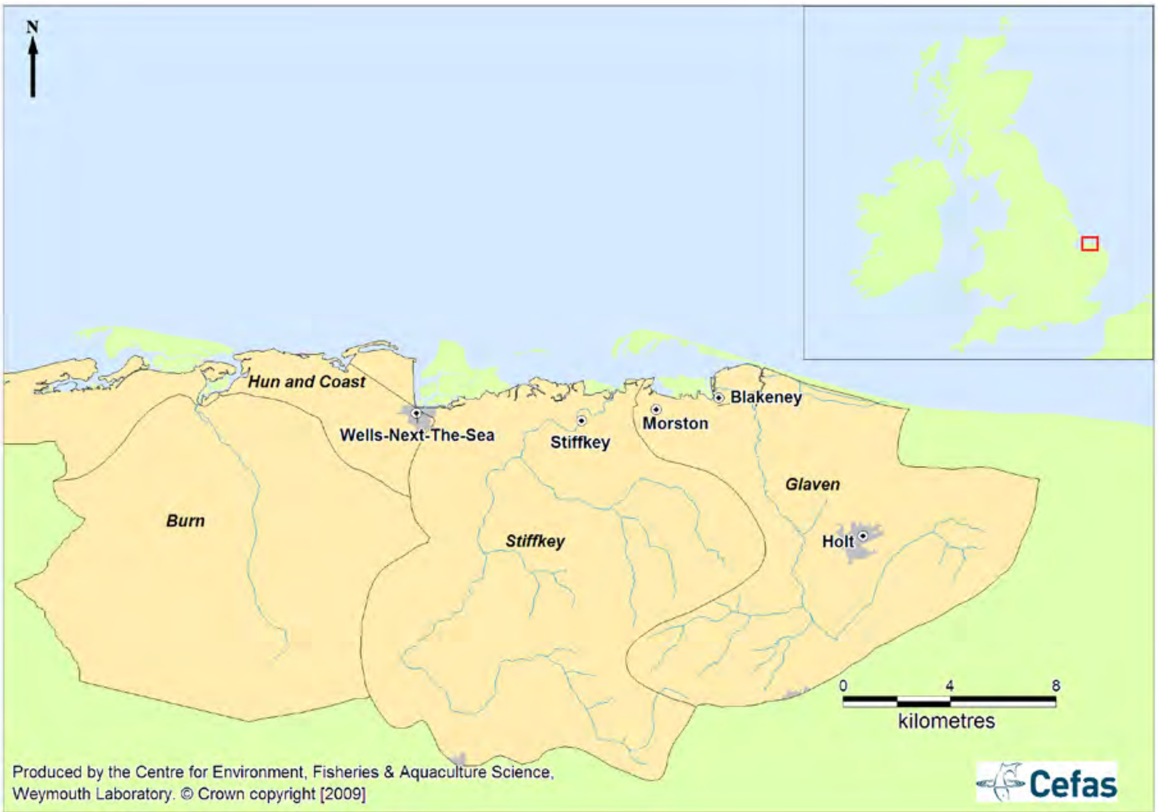


Figure 1.3 Location of sub-catchments draining North Norfolk Coast (central).

Significantly higher geometric means of faecal indicator microorganisms have been found on watercourses during high-flow conditions relative to those during low flow conditions in UK coastal catchments with >50% of improved grassland (Crowther *et al.*, 2002; Stapleton *et al.*, 2006). Given the low levels of grassland

and grazing land found within this catchment area and the relatively low flow of the river, the faecal microbial load is unlikely to be associated with grassland (see Appendix IX).

An assessment of the potential effect of river flows in determining the amount of *E. coli* accumulated by bivalve molluscs is presented in Appendix XI. The potential overall contribution of grassland supporting livestock production to microbiological loads to the estuary is discussed in the Appendix VIII.

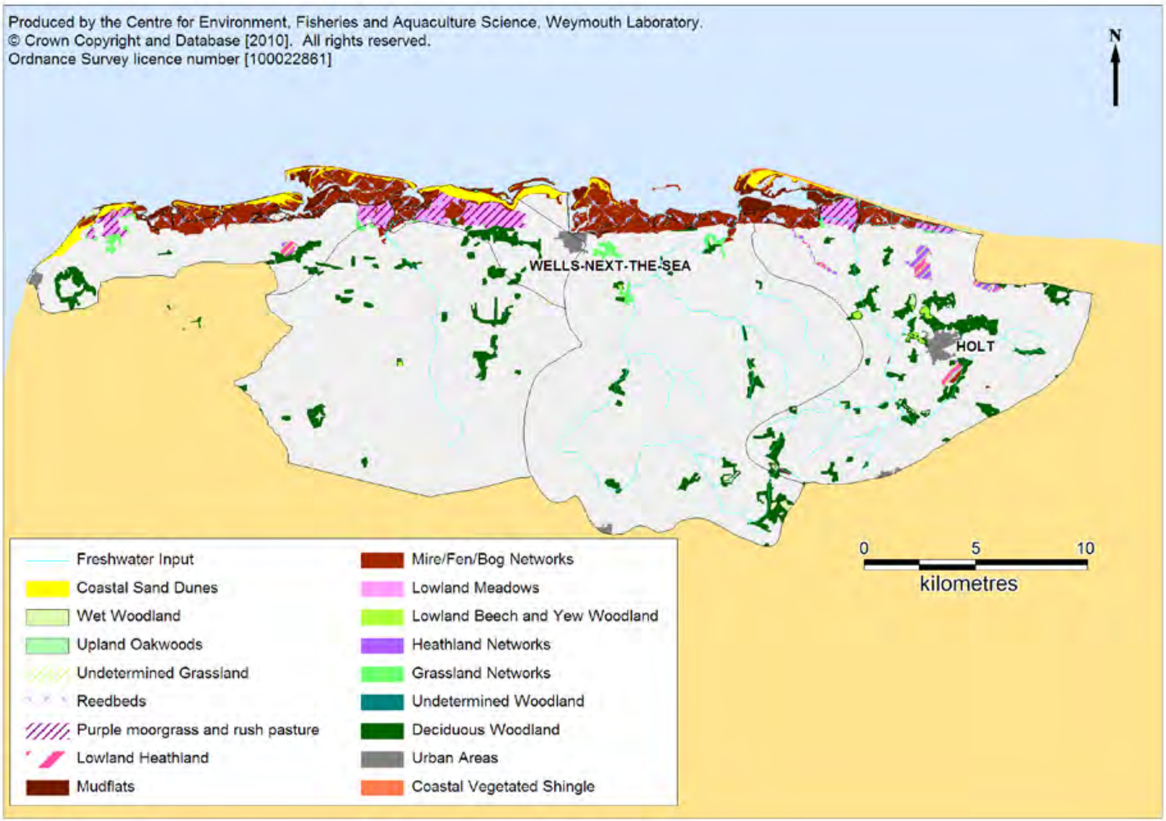


Figure 1.4 Land cover in the Stiffkey catchment.
Boundary data from and regularly updated by Natural England (2008).
(http://www.naturalengland.org.uk).

The area along the coast between Wells-next-the-Sea and Blakeney as well as parts of the Stiffkey and Glavan catchments contain a wide range of habitats and conservation designations (Fig. 1.5), including: Sites of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC), designated under the EC Habitats Directive on the Conservation of Natural Habitats and wild fauna and flora (Figure 1.4).
Special Protection Areas (SPAs), are strictly protected sites classified in accordance with Article 4 of the EC Directive on the conservation of wild birds (79/409/EEC), also known as the Birds Directive. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species. The area is also a RAMSAR site which is a wetland of international importance designated under the Ramsar Convention as well as being a National nature reserve (NNR).

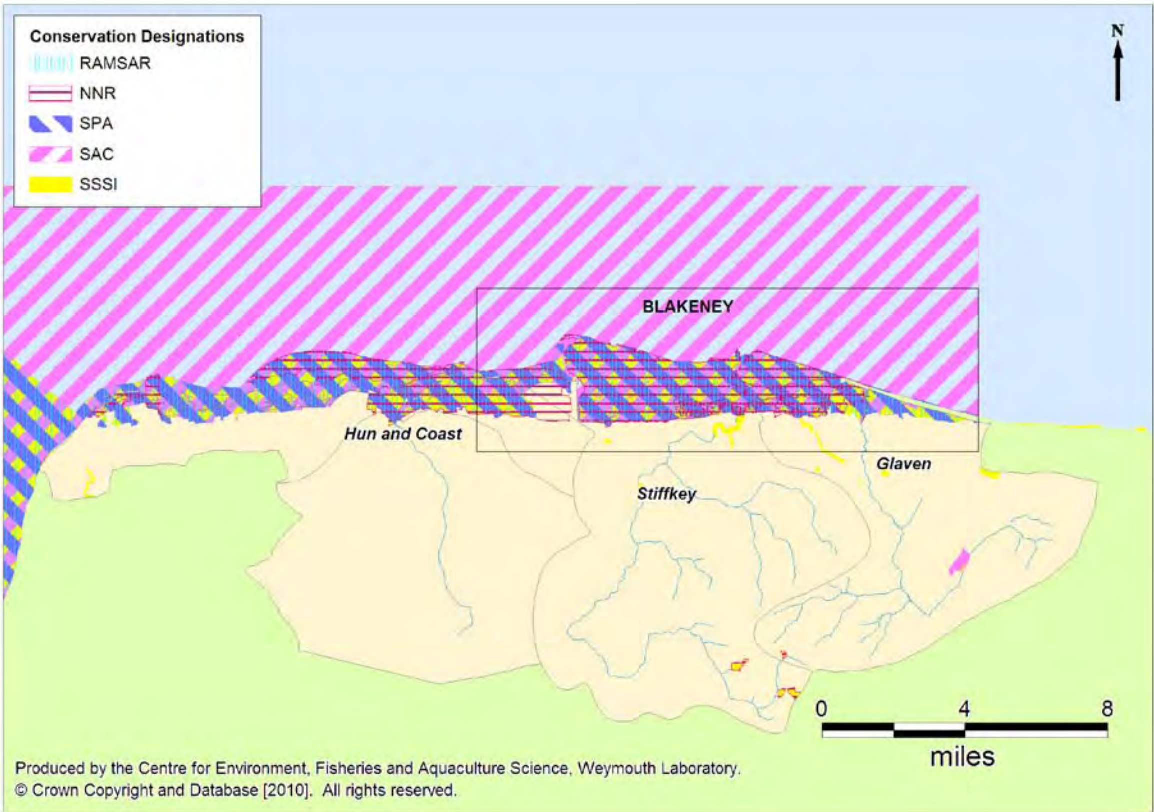


Figure 1.4 Nature conservation designations in catchments draining to Blakeney and Wells-next-the Sea.
Boundary data from and regularly updated by Natural England (2008).
(http://www.naturalengland.org.uk).

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for microbiological monitoring and classification of wild mussels at Wells-next-the-Sea Harbour (Figure 2.1). The locations of this new bed and currently classified beds and representative monitoring points (RMPs) for which data has been analysed for the purposes of this sanitary survey are also shown in Figure 2.1.

The harvesting of bivalve molluscs for human consumption is a traditional activity along the North Norfolk Coast. Illustrations exist of cockle harvesting at Blakeney Haven in 1586. The area around Stiffkey was renowned throughout Norfolk for its cockles known as “Stewkey Blues” (Jackson and James, 1979).

In the past, cockles were also commercially exploited at Bob Hall’s Sand. Cockles inhabit estuarine areas with clean sand, muddy sand, mud or muddy gravel, burrowing to a depth of no more than 5cm, from mid-tide level to just below the low water mark, extending upstream to salinity minimum of about 20% (Tebble 1976). Poor recruitment and/or high mortalities of juveniles have determined the lack of viability of commercial operations for this species in recent times.

Mussels have been harvested for a long time in Blakeney at Simpool Head. Mussels are often found in sheltered estuaries, just below the low water mark, where a food supply of suspended organic detritus and phytoplankton is available (Tebble, 1976). The optimum salinity range for mussel growth is 20–35psu (Laing and Spencer, 2006).

Literature indicates that both *Mytilus galloprovincialis* and *Mytilus edulis* present large morphological, physiological and behavioural similarities in the UK and are therefore difficult to differentiate for commercial purposes due to adaptations to environmental conditions (see Wijsman and Smaal, 2006 and references therein). Data from molecular analyses have demonstrated high levels of hybridisation[1] and gene introgression[2] between these species. Therefore, in the context of the present sanitary survey, taxonomy of mussels is referred at genus level.

Commercial operations for farmed Pacific oysters (*Crassostrea gigas*) were developed at Morston Strand and Freshes Creek, sites that obtained their first classifications in 2003.

[1] The formation of a hybrid organism, e.g. by a cross between genetically dissimilar organisms.
[2] The incorporation of the genes of one species into the gene pool of another species.

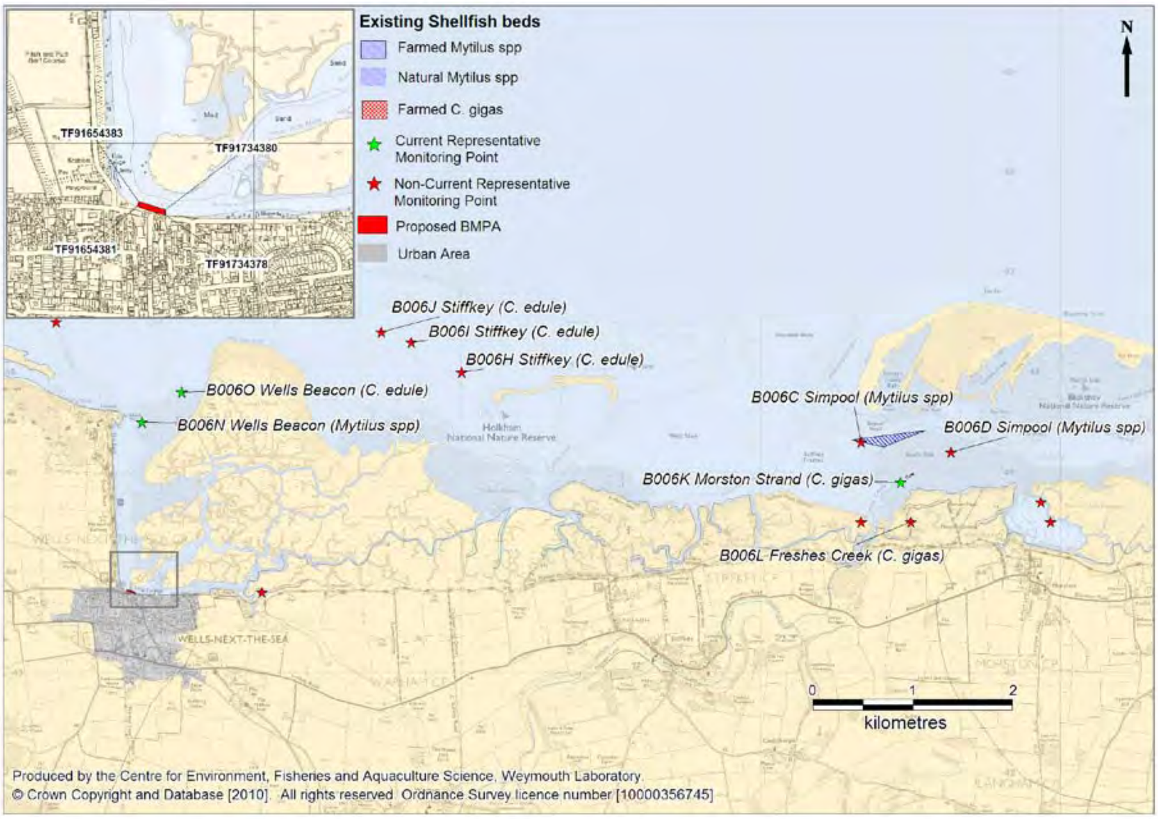


Figure 2.1 Location of the site requiring classification at Wells-next-the-Sea and current and historical Representative Monitoring Points in Blakeney.

<u>HYGIENE CLASSIFICATION</u>

Following the implementation of statutory controls on the commercial production of bivalve molluscs in England and Wales, classifications for mussels (*Mytilus* spp.) and cockles (*Cerastoderma edule*) were initially given for beds situated in the vicinity of Simpool Head (Blakeney) (Table 2.1; Figure 2.1) Figures 2.2 and 2.3 show the extent of currently classified areas in Wells-next-the-Sea and Blakeney.

Table 2.1 Historical classifications of bivalve mollusc production areas in Blakeney for the period 1992–2009.

Bed name	Simpool	Stiffkey	Morston Strand	Freshes Creek	Wells Beacon/ Bob Hall's Sands	Wells Beacon/ Bob Hall's Sands
Bed ID	B006C/D	B006J/I/H	B006K	B006L	B006N	B006O
Species	*Mytilus* spp.	*C. edule*	*C. gigas*	*C. gigas*	*Mytilus* spp.	*C. edule*
Year	-	-	-	-	-	-
1992	A	B	-	-	-	-
1993	A	B	-	-	-	-
1994	B	C	-	-	-	-
1995	A/B	C	-	-	-	-
1996	B	C	-	-	-	-
1997	B	C	-	-	-	-
1998	B	C	-	-	-	-
1999	B	C	-	-	-	-
2000	B	C	-	-	-	-
2001	B	B	n/c	n/c	n/c	n/c
2002	B	B	n/c	n/c	n/c	n/c
2003	B	B	B[1]	B[1]	n/c	n/c
2004	B	B	B	B	B[1]	B[1]
2005	B-LT	B/C	B	B[2]	B	B
2006	B-LT	B/C	B	n/c	B[2]	B
2007	B-LT	n/c	B	n/c	B	B
2008	B-LT	n/c	B	n/c	B	B
2009* provisional	B-LT	n/c	B	n/c	B	n/c

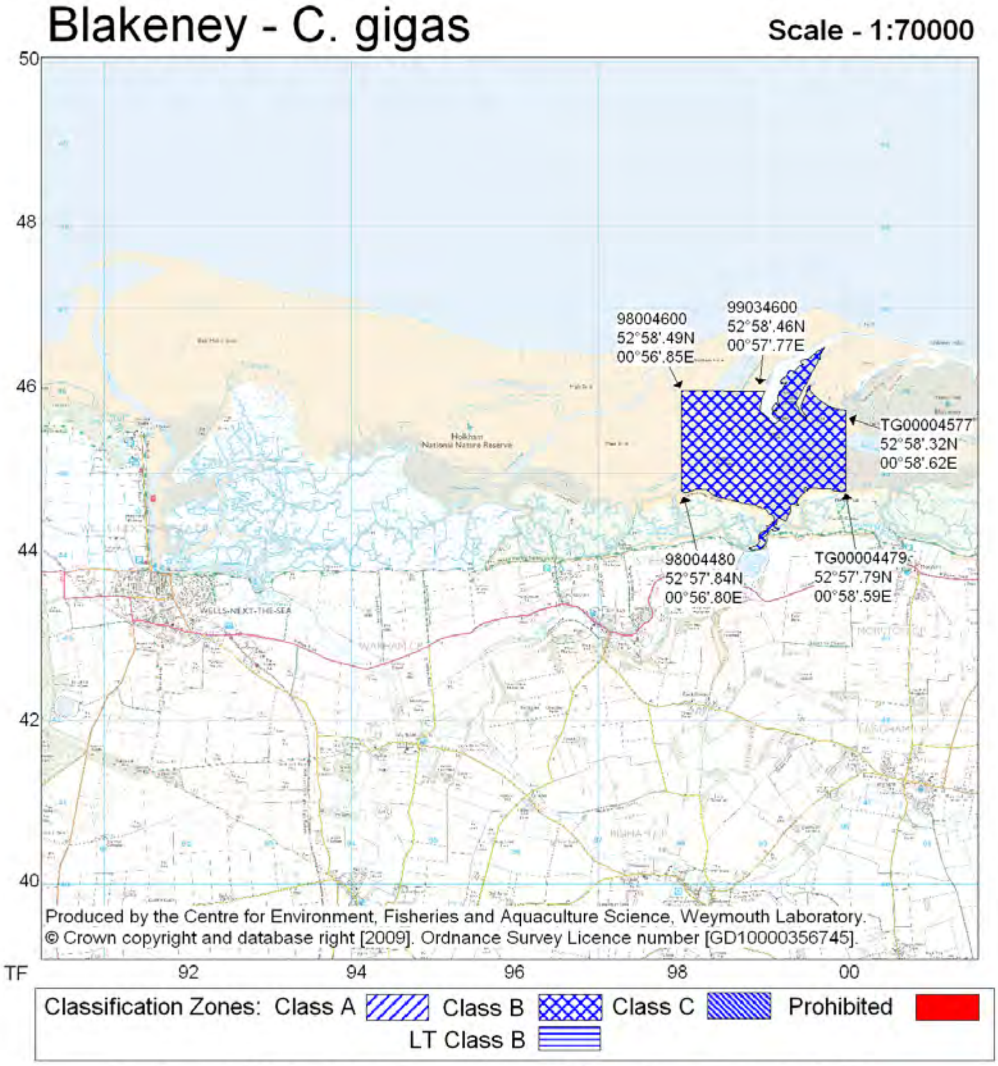
n/c - not classified.
1 - Classification is provisional due to insufficient sample results, either in number or period of time covered.
2 - Area classified at higher level, due to results close to the tolerance limit. A downgrade may be possible if further failures are returned.
LT - Long-Term classification system applies. Note: Long-Term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification.

The post-harvest treatment required before bivalve molluscs can be sold for human consumption is summarised in Table 2.2.

Table 2.2 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 MPN *E. coli* $100g^{-1}$ FIL[2]	None
B	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 4,600 *E. coli* $100g^{-1}$ FIL in more than 10% of samples[3]	Purification, relaying or cooking by an approved method
C	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* $100g^{-1}$ FIL[4]	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited	>46,000 *E. coli* $100g^{-1}$ FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2004.
[3] From EC Regulation 1666/2006.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2009

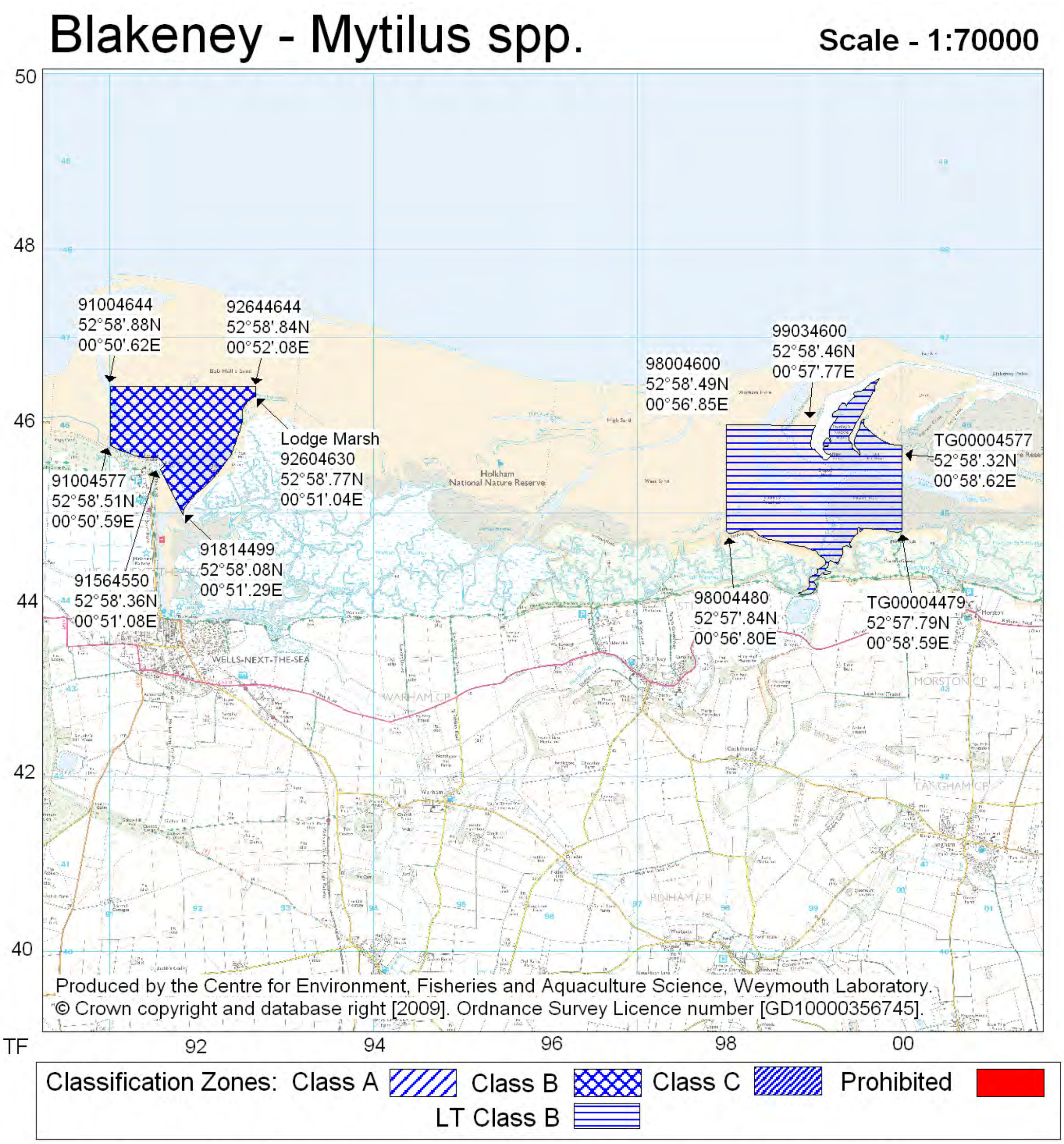
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for Mytilus spp. at Blakeney

Food Authority: North Norfolk District Council

Figure 2.2 Existing classification zone and current classification status for Pacific oysters (*C. gigas*) in Blakeney.



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Separate map available for C. gigas at Blakeney

Food Authority: North Norfolk District Council

Figure 2.3 Existing classification zone and current classification status for mussels (Mytilus spp.) in Wells-next-the-Sea and Blakeney.

2.2 Growing methods and harvesting techniques

Juvenile mussels (seed) are dredged offshore from natural beds along the North Norfolk coast and subsequently relayed onto culture plots known as "lays" at Wells Beacon, Simpool and Wells Harbour, where they grow to commercial size (>45mm). Adult mussels are dredged by hand.

Pacific oysters at Morston Strand grow in bags supported above the riverbed on trestles and are harvested by hand during periods of low water.

2.3 Seasonality of harvest, conservation controls and development potential

The operation at Wells Harbour will be initiated in 2010. The applicant intends to harvest on a seasonal basis (October–March). The estimated annual mussel production in Wells Harbour is 40 tonnes.

Mussels at Wells Beacon and Simpool are also harvested seasonally (October–March).

Harvesting of bivalves in Wells-next-the-Sea is regulated by the Wells Harbour Shellfishery Order (1972). The Wells Harbour Commissioners have a right of regulating the fishery for oysters, mussels, cockles and clams. The area covered by the order is 21 acres, from the South end of the Old Lifeboat House to High Water mark on the opposite shore and the eastern boundary of the Wells Urban District Council (Figure 2.4). The order is in operation for 60 years from 1st April 1972 to 1st April 2032.

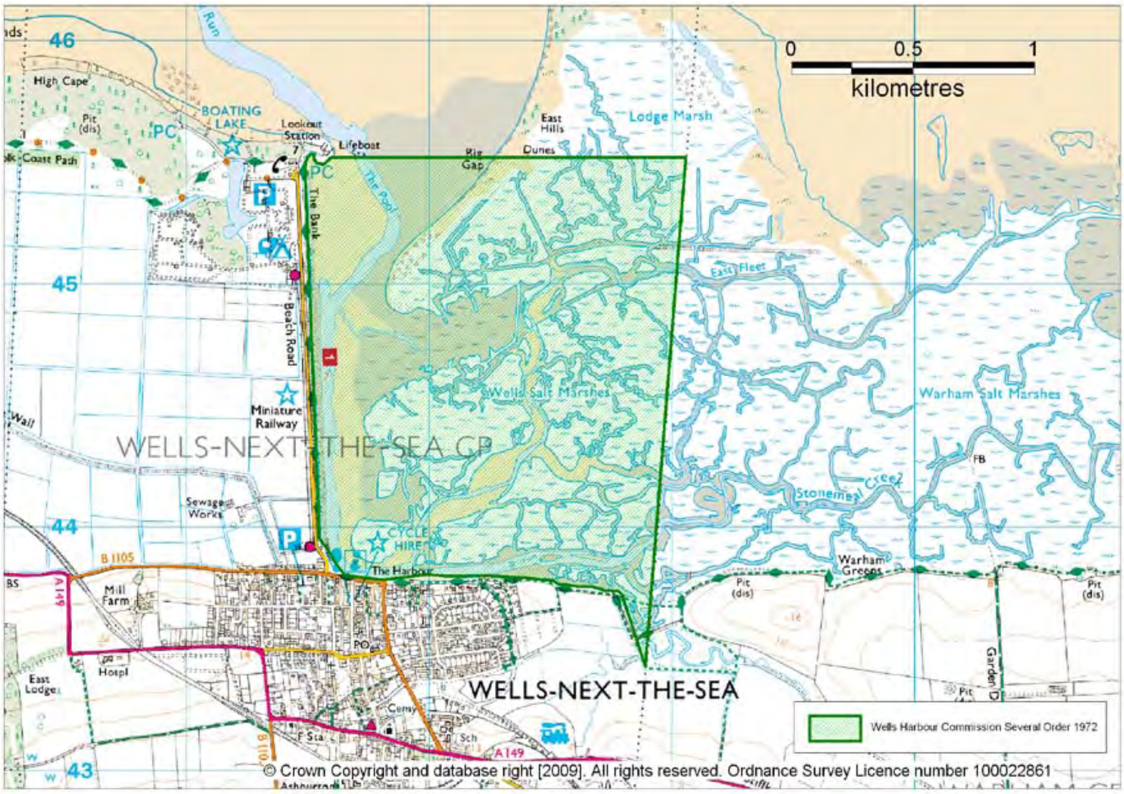


Figure 2.4 Area covered by the Wells Harbour Shell Fishery Order 1972.

At the moment, harvesting of bivalves at Blakeney is not subject to any Several, Regulating or Hybrid Order or other stock conservation controls.

Harvesting periods are summarised in Table 2.3.

Table 2.3 Seasonality of bivalve mollusc harvesting in Blakeney bivalve mollusc production area.

Bed	Species	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Wells Harbour*	*Mytilus* spp.												
Wells Beacon	*Mytilus* spp.												
Simpool	*Mytilus* spp.												
Morston Strand	*C. gigas*												

** Bed requiring classification.*

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of pollution sources on the microbiological contamination of farmed mussels (*Mytilus* spp.) and farmed Pacific oysters (*Crassostrea gigas*) at Blakeney, as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of this bivalve mollusc production area (BMPA).

The survey was prompted by an application for microbiological monitoring and classification of wild mussels *Mytilus* spp. in Wells-next-the-Sea Harbour. The assessment is made in relation to this bed and currently classified beds for mussels and Pacific oysters within the existing BMPA.

SHELLFISHERIES

The area requiring classification for wild mussels in Wells Harbour includes a sub-tidal bed adjacent to the Wells-next-the-Sea quay (approximately 1,330m^2). Other sub-tidal mussel beds are presently classified at The Pool (The Beacon), a tidal delta at the mouth of Wells Harbour, and at Simpool Head, in the mouth of Blakeney Spit Pools.

The BMPA includes a currently classified Pacific oyster bed at Morston Strand, an area of sand and shingle at the South Side of Blakeney Spit Pools. These oysters are grown in bags supported above the riverbed on trestles.

Mussels at Wells Harbour and Blakeney are harvested seasonally, between October and March.

The shellfishery in Wells Harbour is regulated by the Wells Harbour Shellfishery Order (1972). The fishery at Blakeney is not currently subjected to controls determined by Regulating or Several Order.

A shoreline survey undertaken in Wells Harbour and Blakeney Spit Pools and adjacent land allowed the extent of all currently classified beds to be updated.

POLLUTION SOURCES

The BMPA is under the influence of catchments with low levels of development and predominantly used for agriculture. Agricultural activities are mostly arable land for cereals and horticulture. Overall, the risk of diffuse pollution from arable land will be associated with manure and sewage sludge spreading in these areas. However, mussel beds at Wells Harbour are situated in a water body adjacent to the urban area of Wells-next-the-Sea. The risk of diffuse pollution impacting these beds will also be associated with surface runoff from impermeable surfaces (e.g. roads, parks).

Human population in river catchments is higher (total population is over 23,300) than the total number of cattle (over 4,000 animals) and sheep (over 7,400 animals) farmed in the catchment.

Bivalve mollusc beds in the vicinity of the urbanised areas of Wells-next-the-Sea (resident population c. 2,500) will be significantly impacted by sewage discharges; bivalve mollusc beds in Blakeney (resident population = c. 900 people) will be impacted by sewage discharges and runoff from agricultural land.

A number of continuous and intermittent water company sewage discharges were identified as representing a significant or potentially significant impact on the microbial quality of the BMPA. The most significant continuous discharges impacting on the proposed mussel bed is Wells-next-the-Sea Sewage Treatment Works (STW). Warham STW, Great Walsingham STW and Binham STW discharge into the River Stiffkey several kilometres upstream of the town of Stiffkey and will contribute to overall microbiological loadings to the river. Other potentially significant discharges are Stiffkey STW discharges secondary treated effluent to the River Stiffkey approximately 3.4km from the edge of the Pacific oyster bed at Morston Strand. Effluents from Cley-next-the-sea STW receives UV disinfection and discharge into the River Glaven >8km from Morston Strand shellfish bed.

Significantly (Kruskal-Wallis test[3]: H = 19.58; p = 0.000) elevated levels of *E. coli* were found in effluent [post ultraviolet (UV) disinfection] from Wells-next-the-Sea STW during the autumn relative to those during the winter. Therefore, the first two months (October–November) of mussel harvesting in Wells Harbour correspond to the higher risk of faecal contamination from this pollution source.

Levels of the microbiological indicator in effluent [post ultraviolet (UV) disinfection] from Cley next the Sea STW were also examined and these were found to significantly (ANOVA, $F_{3,199}$ = 6.20; p=0.001) increase during the summer. However, median levels of the microbiological indicator during the winter-spring period are below typical levels in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents in the UK. Mussels at Simpool Head are not harvested during the summer and therefore this source does not pose a significant risk of contamination to this species at this bed.

There are no freshwater inputs directly to Wells Harbour. Two rivers drain the wider catchment assessed for the purposes of this sanitary survey: the River Stiffkey, which discharges to Freshes Creek in the vicinity of Stiffkey salt marshes, and the River Glaven, which discharges at Cley next the Sea in the proximity of Fresh Marshes. Both freshwater inputs drain mostly flat land.

Water levels in the River Stiffkey are fairly stable. The delivery of faecal contamination to receiving waters is likely to reflect this stability in river flows.

[3] Datasets were found to be not normally distributed and therefore the assumptions of parametric analysis of variance were violated.

In 2006, the Environment Agency and Natural England identified the North Norfolk Rivers as priority catchments for the Catchment Sensitive Farming Delivery Initiative. The risk of diffuse pollution from agricultural land in these catchments was thought to be associated with cattle poaching of riverbanks along the River Stiffkey. However, a source apportionment model for faecal indicator microorganisms developed by ADAS, CREH and IGER in 2007 predicted higher contributions of pollution sources of human origin than those of animal origin to the overall faecal coliform load within Blakeney catchment.

The Environment Agency considers that moored boats may contribute to faecal contamination in or near the designated Shellfish Water. However, at the time of the shoreline survey, most of the boats moored in the harbour were small vessels without heads. There are pump-out facilities at Wells Harbour, available for those boats with foul water holding tanks.

Wells Harbour and Blakeney Spit Pools support large communities of birds. Water quality in these water bodies could be vulnerable to faecal contamination from these animals, in particular from waterbirds. Analysis of published information on bird distribution and abundance highlighted that different species use different areas of Wells Harbour at different times due to the diversity of natural habitats. Key feeding areas in the harbour include the saltmarsh and low-lying sandflats along the navigational channel and Bob Hall's Sand. These areas are in close proximity to mussel beds at Wells-next-the-Sea. Birds are considered significant sources of faecal contamination. Due to the small scale of these mussel beds, it is not possible to determine locations for monitoring points or a modified sampling strategy uniquely based on bird distribution. Consideration is however given to these and other potentially significant sources of pollution for the purposes of informing the sampling plan (Figure 3.1).

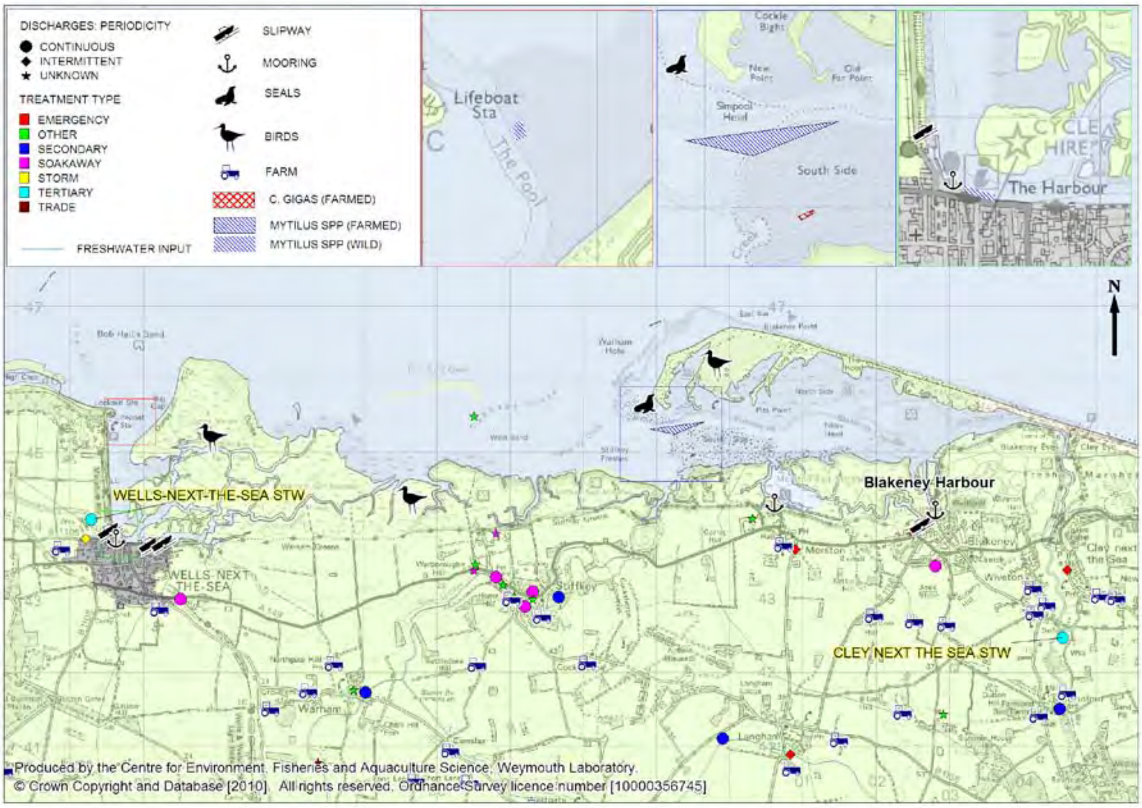


Figure 3.1 Significant pollution sources impacting on the microbial status of bivalve mollusc production areas at Wells-next-the-Sea and Blakeney.

HYDRODYNAMICS

The bivalve mollusc beds assessed in this sanitary survey occur in two distinct physiographical units: Wells Harbour, a large tidal delta and Blakeney Spit Pools, a percolating saline coastal lagoon. Seawater enters Blakeney Spit Pools by percolating through the network of channels around shallow shingle banks and sandflats. In Wells Harbour, tidal currents force seawater to enter the inlet via one main navigational channel, (approximately 2m at Chart Datum) just south of the Lifeboat Station peninsula connecting the harbour and the sea at Bob Hall’s Sand. This facilitates water exchange with the sea and will markedly affect the persistence of microbiological pollutants. Tidal flushing is assumed to increase towards Bob Hall’s Sand (Wells Harbour) and Blakeney Harbour (Blakeney Spit Pools).

Although significant areas of Wells Harbour and Blakeney Spit Pools dry at low water springs, all mussel beds are totally or mostly (in the case of Simpool Head) sub-tidal. Under these circumstances, mussels will be exposed to potentially contaminated waters over the whole tidal cycle.

In contrast, Pacific oysters at Morston Strand are exposed during significant periods of the tidal cycle. This will reduce filtration activity and restrict the potential to accumulate contaminants or self-purify to periods when the beds are covered by the tide.

SUMMARY OF MICROBIOLOGICAL DATA

Levels of faecal coliforms in surface waters at Wells-next-the-Sea designated Bathing Water (700m west of the Harbour entrance) have been excellent, without any samples exceeding the Imperative value during the bathing season.

The sampling effort for the purposes of the Shellfish Waters monitoring programme has been low in recent years and this has constrained an assessment of the microbial water quality at Blakeney Spit Pools, where the monitoring point is currently established.

Analysis of historical *E. coli* data in bivalves from the Shellfish Hygiene monitoring programme suggested the following relationships in contaminating levels between classified beds:

- Wells Beacon>Simpool (mussels);
- Stiffkey≈Wells Beacon (cockles);
- Freshes Creek>Morston Strand (Pacific oysters).

Despite an overall increasing trend in monthly mean levels of *E. coli* in bivalves from spring to autumn, these seasonal differences are not statistically significant and are less than 1Log_{10}. This suggests that a monthly sampling regime will adequately represent the temporal variation of microbiological contamination in all beds of Blakeney BMPA.

As suggested by the inventory of pollution sources and hydrodynamic assessment, mussels from Simpool have shown an overall better microbial quality than mussels in Wells Harbour. This is likely to be associated with the location of the monitoring point at Blakeney Harbour, where tidal flushing is high and the potential for contamination via freshwater inputs is low most of the time.

In contrast, mussels from Wells Beacon have shown the highest levels of contamination. Considering that water quality at Wells Harbour quay area is impacted by various sources of faecal contamination and more restricted water exchange with the sea occurs in this area, it is expected that the new mussel bed at Wells Harbour may show occasional periods of deteriorated microbial quality during the harvesting season.

Statistically significant positive correlations were found between rainfall and levels of *E. coli* in mussels from Simpool Head and daily rainfall on the second day before sampling and cumulative rainfall between the third and fourth days before sampling. Sampling to target the impact of rainfall events may better reflect the worst-case scenario of contamination in mussels at Simpool, if this aspect of the *European Union Good Practice Guide for Microbiological Monitoring of Bivalve Mollusc Harvesting Areas* (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007) is adopted in the UK at some time in the future.

Levels of *E. coli* in mussels at Wells Beacon on the day of sampling were also found to be positively associated with water levels in the River Stiffkey on the day of sampling. Graphical representation of this relationship suggested that sampling mussels at this site when water levels in this river are above the mean flow level ($0.2m^3\ s^{-1}$) is likely to represent the worst-case scenario of contamination.

4. RECOMENDATIONS

Where adjustments are made with respect to locations of existing representative monitoring points or recommendation for new RMPs are given, these are assigned a new name and ID code.

- Boundaries for three classification zones for mussels should be defined.
- One classification zone encompassing the ‘The Pool’ bed at Wells-next-the-Sea.
- The second classification zone encompassing the bed at Wells Harbour.
- The third classification zone encompassing the bed at Simpool Head.
- The RMP B006N (Wells Beacon) for mussels at Wells-The Pool should be replaced by a new RMP at the centre of the mussel bed to adequately reflect the impact of pollution sources. The maximum recommended tolerance for this RMP is 10 metres due to the restricted area of operation and no foreseeable difficulties in obtaining samples.
- The RMP B006C (Simpool) for mussels at Simpool Head should be replaced by a new RMP at the eastern edge of the mussel bed to adequately reflect impact of pollution sources, as summarised above. The maximum recommended tolerance for this RMP is 10 metres due to being no foreseeable difficulties in obtaining samples.
- A new RMP is necessary for mussels at Wells Harbour, to adequately reflect the impact of microbiological contamination of agricultural land from the Stiffkey catchment, water activities within the Harbour and sewage discharged directly to the sea or via watercourses in the Wells area. Due to the restricted water exchange of this area it is expected that mussels at Wells Harbour will show periods of deteriorating quality, such as during the tourism season. The maximum recommended tolerance for this RMP is 10 metres due to the restricted area of operation, and no foreseeable difficulties in obtaining samples.
- A boundary for a classification zone for Pacific oysters should be defined. The classification zone should encompass the bed at Southside.
- The RMP B006K should be replaced by a new RMP at the centre of the pacific oyster bed to adequately reflect the impact of pollution sources. The maximum recommended tolerance for this RMP is 10 metres, due to

the restricted area of operation, and no foreseeable difficulties in obtaining samples.

- The recommended sampling plan presented represents an increase in RMPs for mussels (2 to 3) and no change in the number of RMPs for pacific oysters (1).

- Consideration could be given by the Local Enforcement Agency to suspend mussel sampling during the closed season (April–July).

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Blakeney
Cefas Main Site Reference	M006
Cefas Area Reference	FDR 3024
Ordnance survey 1:25,000 map	Explorer 251: Norfolk Coast Central: Wells-next-the-Sea & Fakenham showing part of the Norfolk Coast Path
Admiralty Chart	Admiralty 108: Approaches to The Wash

Shellfishery

Species	Culture	Seasonality of harvest
Mussels (*Mytilus* spp.)	Wild	October–March
Pacific oysters (*Crassostrea gigas*)	Farmed	year-round

Local Enforcement Authority

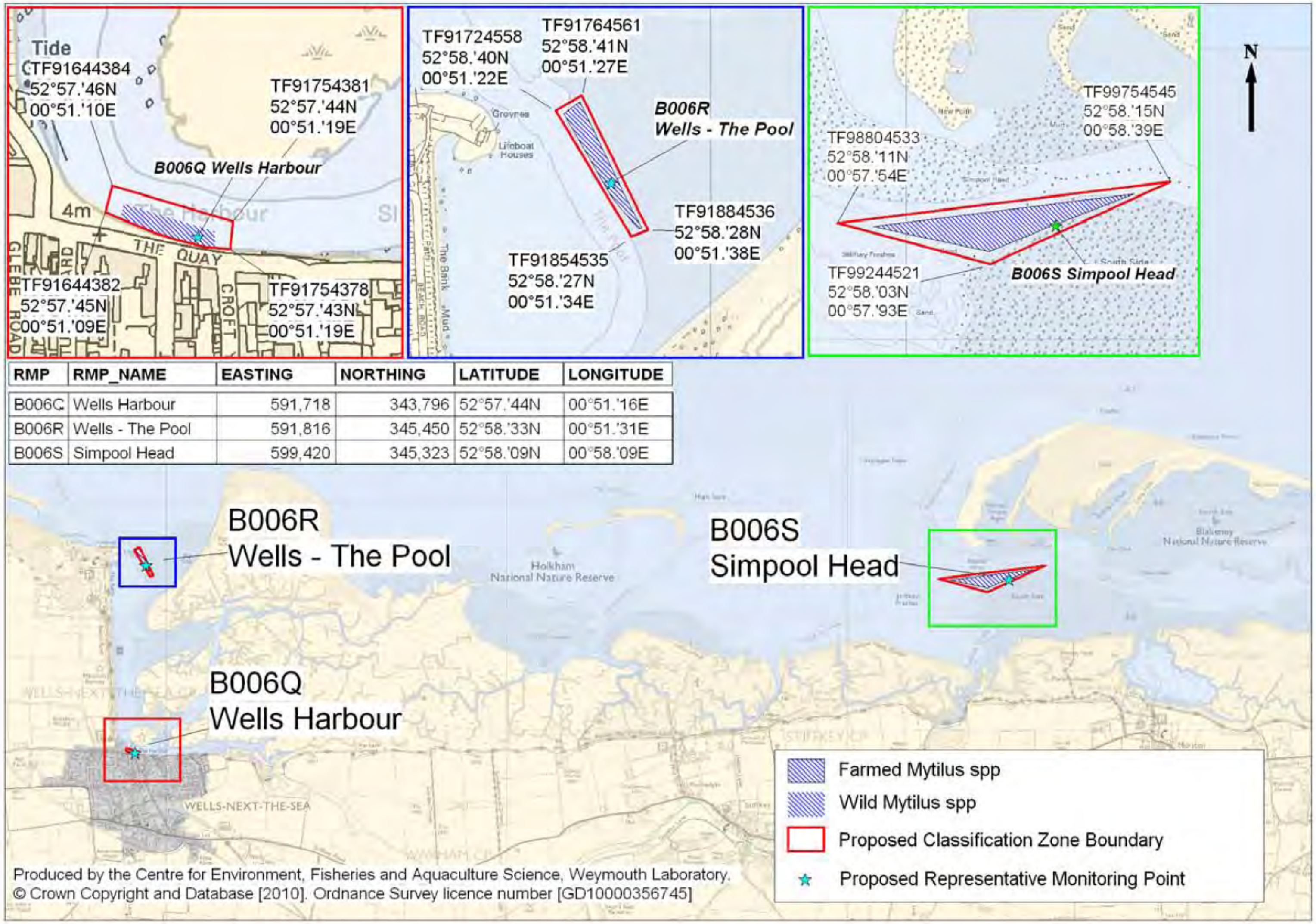
Name of Local Enforcement Authority	North Norfolk District Council, Environmental Health Department, Council Offices Holt Road CROMER Norfolk NR27 9EN
Telephone number ☎	01263 513811
Environmental Health Officer	Claire Kinsley
Telephone number ☎	01263 516240
Fax number	01263 514627
E-mail	Claire.Kinsley@north-norfolk.gov.uk

Requirement for Review

The need for this sampling plan to be reviewed will be assessed by the competent authority within six years or in light of any obvious known changes in sources of pollution of human (e.g. improvements in sewage treatment works) or animal origin likely to be a source of contamination for the bivalve mollusc production area.

Table 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones in Blakeney.

Classification zone			Wells-next-the-Sea	Wells-next-the-Sea	Blakeney	Blakeney
RMP			**B006Q**	**B006R**	**B006S**	**B006T**
RMP name			**Wells Harbour**	**Wells - The Pool**	**Simpool Head**	**South Side**
Geographic grid references (datum) of sampling points	**Easting** **Northing**		591,718 343,796	591,816 345,450	599,420 345,323	599,502 344,955
	NGR		TF 9171 4379	TF 9181 4545	TF 9942 4532	TF 9950 4495
	WGS84	**Latitude** **Longitude**	52°57'.44N 00°51'.16E	52°58'.33N 00°51'.31E	52°58'.09N 00°58'.09E	52°57'.89N 00°58'.15E
Species			*Mytilus* spp.	*Mytilus* spp.	*Mytilus* spp.	*C. gigas*
Growing method			Seabed cultivation	Wild	Seabed cultivation	Bags on trestles
Harvesting technique			Hand-dredged	Hand-picked	Hand-picked	Hand-picked from bags
Sampling method			Hand-dredged	Hand-picked	Hand-picked	Hand-picked from bags
Depth (m)			Seabed	Seabed	Seabed	Seabed
Tolerance for sampling points (m)			10	10	10	10
Frequency of sampling (PRELIMINARY Classification)			10 samples taken over, at least,3 months	-	-	-
Frequency of sampling (FULL Classification)			At least monthly over one year	At least monthly	At least monthly	At least monthly



RMP	RMP_NAME	EASTING	NORTHING	LATITUDE	LONGITUDE
B006C	Wells Harbour	591,718	343,796	52°57.'44N	00°51.'16E
B006R	Wells - The Pool	591,816	345,450	52°58.'33N	00°51.'31E
B006S	Simpool Head	599,420	345,323	52°58.'09N	00°58.'09E

Figure 5.1 Location of recommended representative monitoring points (RMPs) and classification zone boundaries for mussels in Blakeney.

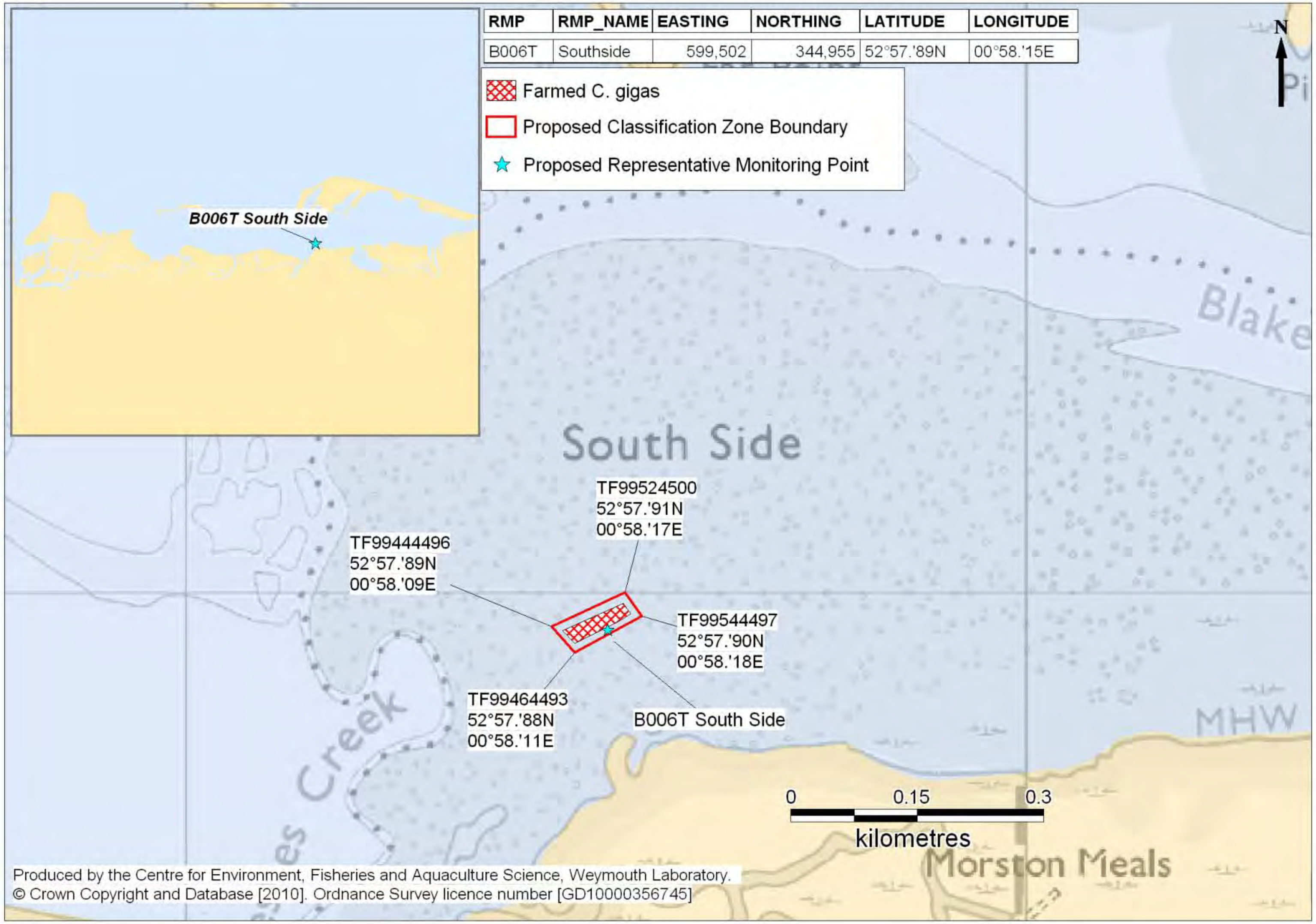


Figure 5.2 Location of recommended representative monitoring points (RMPs) and classification zone boundaries for Pacific oysters in Blakeney.

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population totally or partially included within the river catchment areas is shown in Figure 1.1. Population density by Super Output Area Boundary[4] has its maximum value at Fakenham (>2.5 people per hectare). Maximum density at Wells-next-the-Sea is 5 people.

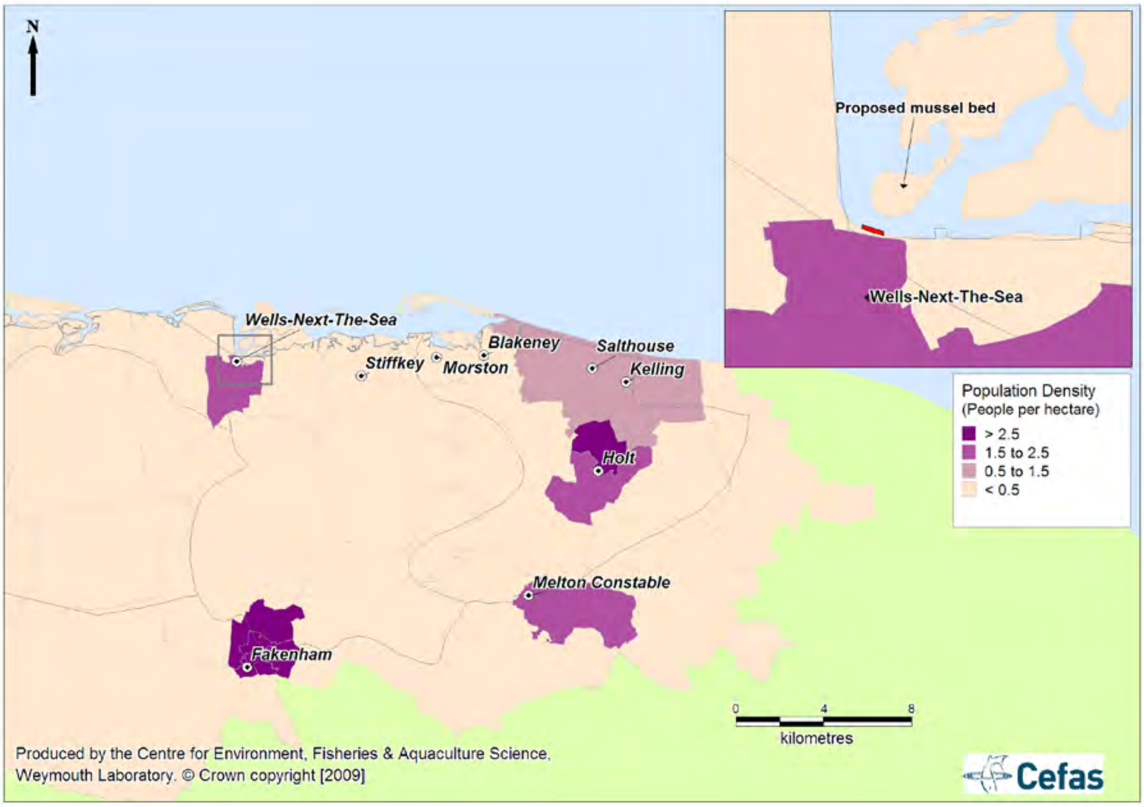


Figure I.1 Human population density in the Stiffkey river catchments.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Total resident population within river catchments is summarised in Table I.1.

Table I.1 Resident population in catchments draining to Wells Harbour and Blakeney lagoon.

River catchment	Population
Burn	3,784
Glaven	9,127
Hun and Coast	4,605
Stiffkey	5,837
Total	23,353

Data from Office for National Statistics (2007). N.B. Mid-2005 population estimates for river catchment areas within England and Wales.

[4] Super Output Area (SOA) boundaries are in part derived from Ordnance Survey information and some SOA boundaries which follow ward or parish boundaries reproduce limited parts of the OS Boundary-Line product.

The urban area of Wells-next-the-Sea contains 42% of the total population within the Stiffkey catchment (Table I.1).

Table I.1 Human population in significant urban areas in the Stiffkey catchment.

Town	Resident population
Wells-next-the-Sea	2,451
Blakeney	875
Salthouse	196
Kelling	515
Holt	3,550
Melton Constable	782
Stiffkey	225
Fakenham	7,360
Total	15,954

Source: Office for National Statistics, Crown copyright 2007. Crown copyright material is reproduced with the permission of the Controller of HMSO.
NB. Based on provisional mid-2005 population estimates for river catchment areas within England and Wales.

Urbanised areas concentrate the majority of point-sources of pollution (continuous and intermittent sewage discharges) in these catchments. An inventory of the significant sewage discharges to the estuary is presented in Appendix VII. Urbanised areas also contain the vast majority of impervious surfaces[5] (e.g. roads, parks, pavements), which are known to contribute significant loads of microbiological contaminants (see Ellis and Mitchell, 2006)[6]. Bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

There is no heavy industry in the catchments. Agriculture and tourism represent the main activities in terms of local economy. Wells Harbour supports a variety of sailing activities, both for locally-owned boats and visiting vessels (Wells Harbour, 2009). A variety of other water-based recreational activities take place in the harbour area during the spring-summer, including wind-surfing, water skiing and canoeing (Wells Harbour, 2009).

The top tourism attractions in Wells-next-the-Sea are Holkham Hall and Wells Harbour Railway (Enjoy England, 2009). In 2003, approximately 20,000 people visited the railways (North Norfolk District Council, 2005).

Seasonal changes in human population due to tourism will result in increased microbiological loads from sewage treatment plants on a seasonal basis (Younger *et al.*, 2003).

[5] In the context of the present report, impervious surfaces are any surface in the urban landscape that does not infiltrate rainfall.
[6] Concentrations of *E. coli* (MPN $100ml^{-1}$) quoted in literature are: $10–10^3$ for residential areas and highways and $10^2–10^4$ for roof runoff and commercial areas (Ellis and Mitchell, 2006).

APPENDIX II
HYDROMETRIC DATA: RAINFALL

The pattern of rainfall variation in England and Wales tends to be associated with Atlantic depressions or with convection, atmospheric humidity and altitude (Met Office, 2007). Norfolk is one of the driest counties in England, with an average rainfall of only 625mm (Norfolk State of the Environment Report, 2003). This compares with an average annual rainfall for England and Wales of approximately 1,250 mm (Perry, 2006).

Historical data from the network of stations maintained by the Met Office shows a much more even distribution of rainfall throughout the year in Eastern England than in most other parts of the UK. This is due to the combined effect of the rain-shadow for winter Atlantic depressions produced by higher grounds to the west and higher frequency of convective rainfall in summer (Met Office, 2009).

Figure II.1 shows the location of two rainfall gauging stations in the Stiffkey catchment from which data was analysed for the purposes of this survey.

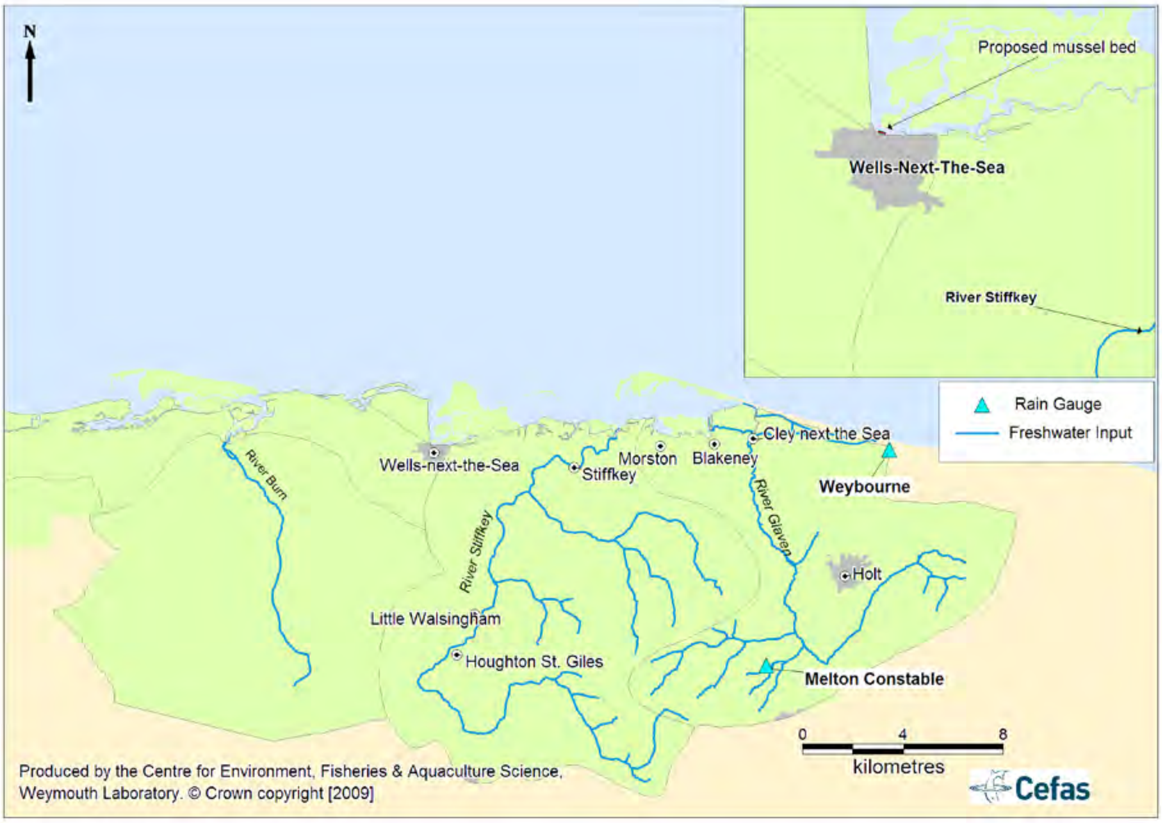


Figure II. 1 Freshwater inputs and location of rainfall gauging stations in the Stiffkey, Burn and Glaven catchments.

Figure II.2 shows monthly averaged and monthly total rainfall monitored daily at rainfall gauges installed at Melton Constable (Easting/Northing: 605,000/334,990) for the period January 2000−May 2009 and Weybourne (609,890/343,580) for the period January 2000–May 2002.

On average, the drier months were in spring (February – April). The wetter months were August–December. Lower levels of rainfall were measured in the gauging station representative of the lower reaches of the catchment.

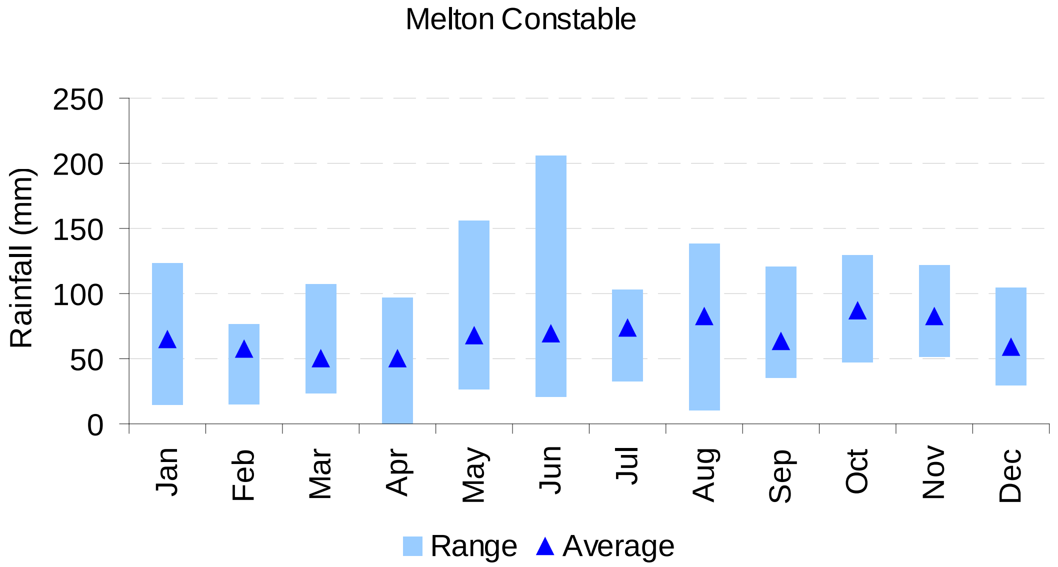


Figure II.2 Monthly variation of rainfall recorded at Melton Constable gauging station for the period January 2000–May 2009
Data from the Environment Agency (2009).

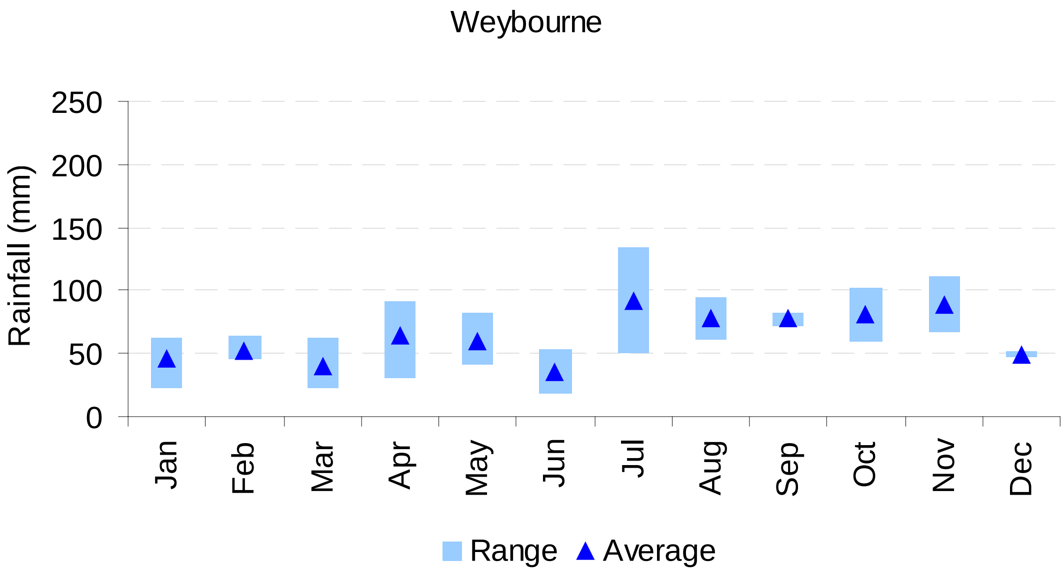


Figure II.2 Monthly variation of rainfall recorded at Weybourne gauging station for the period January 2000–May 2002
Data from the Environment Agency (2009).

Levels of microbiological contamination may increase following rainfall events. Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al*., 2003). The most significant sewage discharges to the Stiffkey and Glaven catchments are listed in the Appendix VII. Representative monitoring points located in that part of the shellfish bed closest to discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

There are no major freshwater inputs directly into Wells Harbour. The nearest significant freshwater inputs are the River Stiffkey and River Glaven, which discharge to the lagoon at Blakeney and the River Burn, which discharges to the West of the BMPA at Burnham Overy (Figure III.1).

Figure III.1 Rivers and streams in catchments draining to Blakeney bivalve mollusc production area.

The River Burn (also known as "Nelson's River"), from its headwaters in the vicinity of Leicester Square Farm [altitude = 83m above Ordnance Datum (OD)] to where it enters the sea at Burnham Overy is approximately 11km (Figure III.1). This river is shallow, narrow and fast flowing until it approaches the mills at Burham Thorpe and Burnham Overy where it deepens and broadens (Environment Agency, 1996). The mouth of this river is approximately 8km from the nearest mussel bed at Wells Beacon. The River Burn is considered to represent a significant freshwater input potentially impacting the fishery purely on the basis of (a) its fast flowing characteristic; (b) the prevalent nearshore sediment fluxes run parallel to the coast on a West-East direction (see HR Wallingford *et al.*, 2002) and (c) the existence of significant sewage discharges in the catchment.

The River Stiffkey, from its headwaters on Swanton Novers [altitude = 97m above OD] to where it enters the sea at Freshes Creek is approximately 33km (Figure III.1). The river meanders through arable countryside, passing Great Snoring, Walsingham and Stiffkey. Its most significant tributary is Binham Stream, which joins the River Stiffkey at Warham (Environment Agency, 1996). The mouth of this river is approximately 400m from the Pacific oyster bed at Morston Strand.

The River Glaven, from its headwaters in the vicinity of Baconsthorpe and Bodham [altitude = 79m above OD] to where it enters the sea at Cley next the Sea is approximately 17km (Figure III.1). The river has two major tributaries: the Stody Beck and the Thornage Beck. It flows westwards past Holt Lowes Site of Special Scientific Interest, Letheringsett Mill and Glandford Mill (Environment Agency, 1996). Its mouth is approximately 3km from the mussel bed at Simpool.

At lower catchment levels, the river Stiffkey has higher mean flows, Q95 and Q10 than the River Burn (Table III.1). This indicates a potentially significant higher contribution of the River Stiffkey than that from the River Burn for overall microbial delivery to the coastal area.

Table III.1 Hydrological characteristics for significant freshwater inputs in catchments draining to Blakeney bivalve mollusc production area.

	Stiffkey (Little Walsingham)	Stiffkey (Warham All Saints)	Burn (Burnham Overy)
Grid reference	53 (TF) 935 366	53 (TF) 944 414	53 (TF) 842 428
Catchment area (km^2)	49.3	87.8	80
Level of station (m OD)	20	5.3	2.6
Maximum altitude (m OD)	-	98	81
Mean flow ($m^3 s^{-1}$)	0.21	0.54	0.32
95% exceedance (Q95) ($m^3 s^{-1}$)	0.222	0.127	0.093
10% exceedance (Q10) ($m^3 s^{-1}$)	0.206	1.002	0.56

Data from the National River Flow Archive (NERC-CEH, 2009). River Glaven not gauged.
NB. Q95 and Q10 represent the averaged flow that is exceeded for 95% and 10% of the time, respectively.

Figure III.2 shows the relatively constant flow rate in the River Stiffkey. Microbial loads are therefore expected to be fairly constant throughout the year.

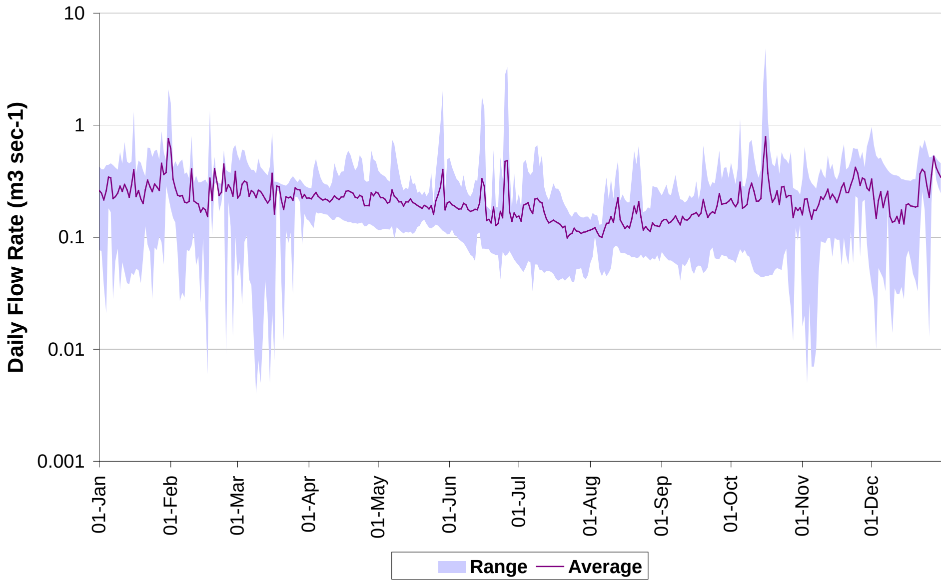


Figure III.2 Hydrograph for River Stiffkey (Little Walsingham) for the period Jan 2000–June 2009.
Data supplied by the Environment Agency (2008).

APPENDIX IV
HYDRODYNAMIC DATA: BATHYMETRY

WELLS HARBOUR

Bathymetric contours with upper and lower limits of 3m and -3 relative to Chart Datum (CD) respectively are shown in Figure IV.1.

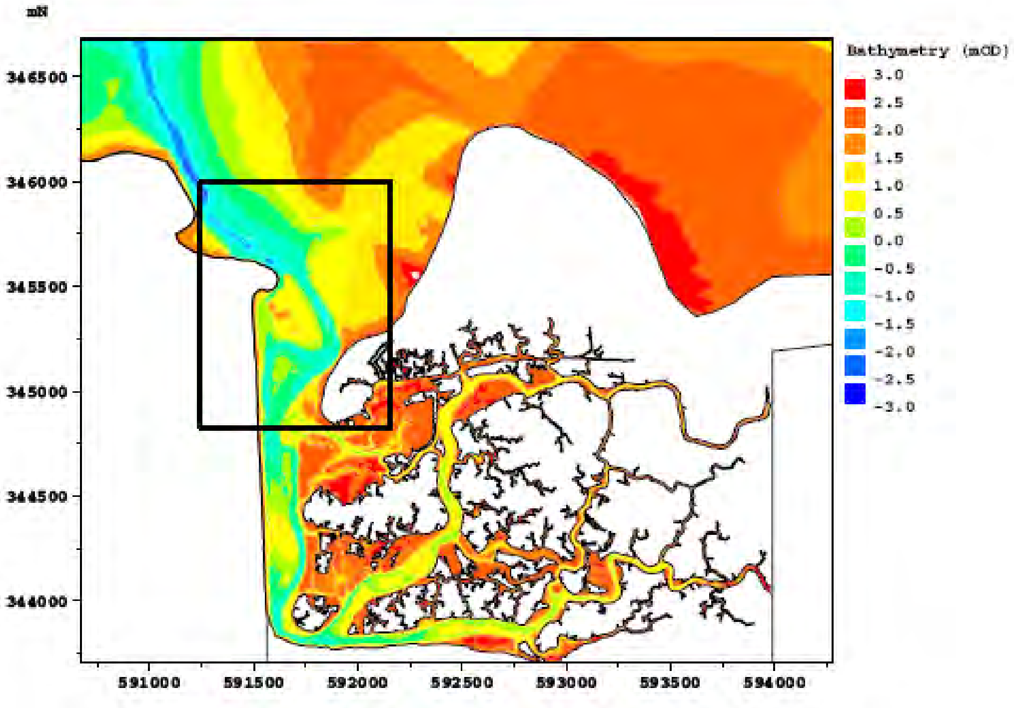


Figure IV.1 Bathymetry in Wells Harbour.
Modified from HR Wallingford Ltd. (2009).

One main navigational channel maintains communication between Wells Harbour and Bob Hall's Sand (Figure IV.2).

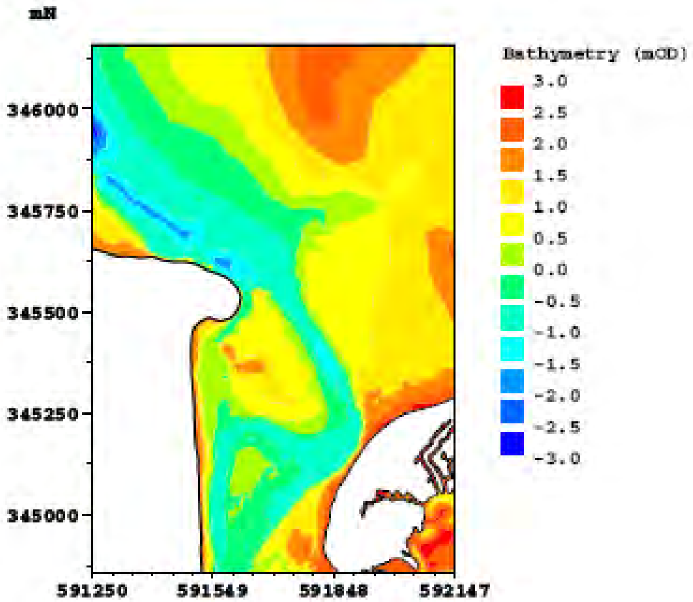


Figure IV.2 Bathymetry in the mouth of Wells Harbour.
Modified from HR Wallingford Ltd. (2009).

From this figure, it is evident that most of the harbour dries completely at low water springs. Most of the drying areas occur along the margins of the navigational channel and in the saltmarsh.

Mussel beds at Wells Beacon are shown in drying areas in Figure IV.3. However, during a shoreline survey undertaken in the harbour on 7 July 2009, it was noted that the bed is subtidal. From the published literature, it is known that this channel is subject to constant change due to the effect of wind-driven currents and tidal influence. Therefore, it is assumed that the hydrographic chart is not adequately representing bathymetry in this area.

Figure IV.3 Bathymetry in Wells Harbour showing the new mussels bed at The Quay and Wells Beacon.

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Reproduced from Imray Chart Y9 - The Wash with the permission of the publishers.

BLAKENEY SPIT POOLS

Most of the mussel lays at Simpool Head (Figure IV.4) occur along the main low water channel establishing communication between the inner lagoon and Blakeney Harbour. Bathymetric contours show that portions of the southern edge of the bed will dry on low water springs.

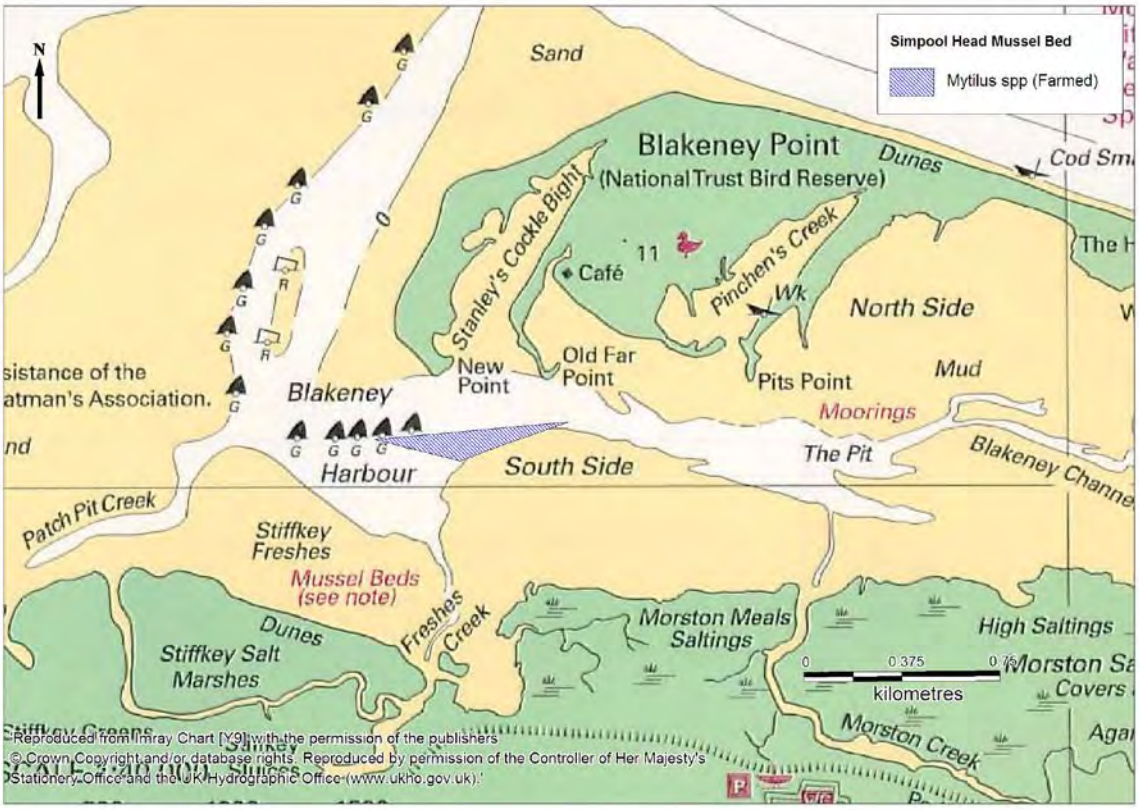

Figure IV.4 Bathymetry in Blakeney Harbour showing the mussel bed at Blakeney Harbour.

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Reproduced from Imray Chart Y9 - The Wash with the permission of the publishers.
NB. Mussel beds marked on the map are not currently classified.

Mussels in subtidal areas have the potential to accumulate microbiological contamination over the whole tidal cycle.

Pacific oyster bags at Morston Strand are exposed during significant periods of the tidal cycle (Figure IV.5). At the time of the shoreline survey, it was also noted that this bed is situated within a small pool. This will extend filtration periods over which oysters may be retaining contamination.

Differences in bathymetry between the Wells Harbour area and Bob Hall's Sand and between Blakeney percolating lagoon and the outer Blakeney Harbour area will influence the advection and dispersion of contamination over bivalve mollusc beds, in particular affecting decay rates of microorganisms. In general, less dilution of contaminants will occur in Wells Harbour and inner area of the percolating lagoon.

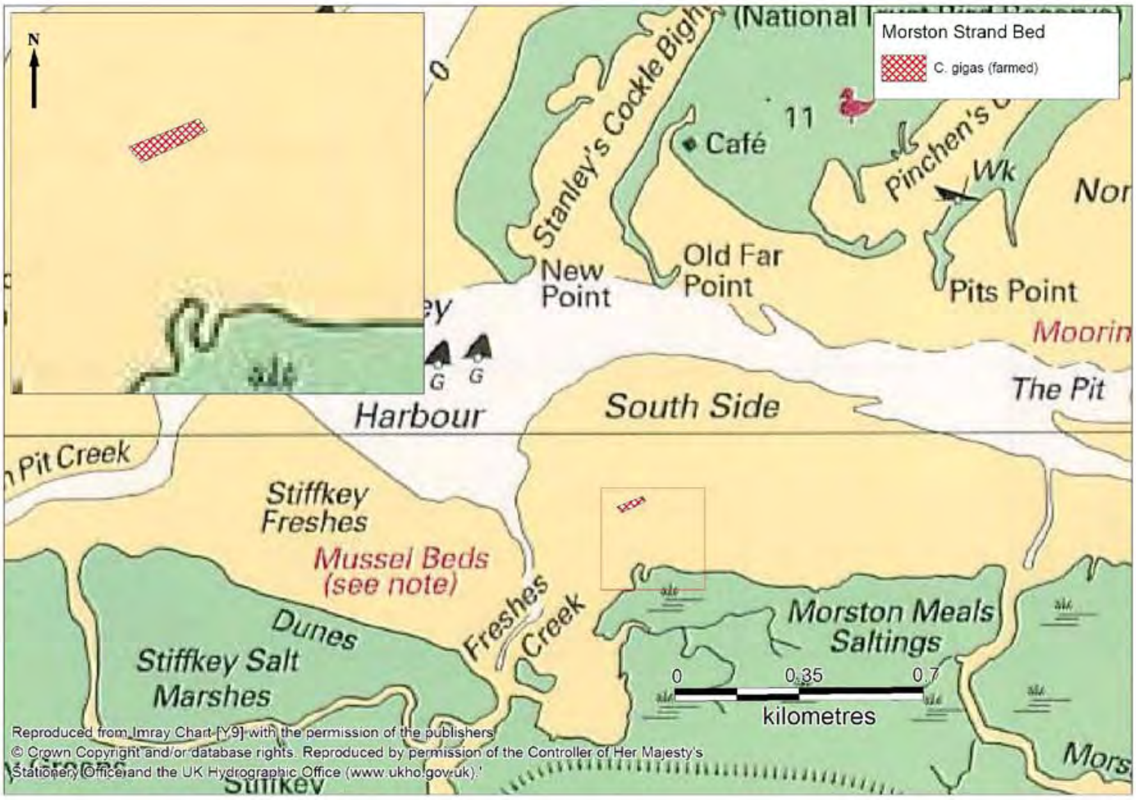

Figure IV.5 Bathymetry in Blakeney Harbour, showing the Pacific oyster bed at Moston Strand.

Extensive drying areas often produce continued drainage long after the tide has receded and the mudflats are exposed (see Whitehouse *et al*., 2000). Contaminated runoff from retained seawater and/or washed off by rainfall falling on the surface of mudflats into these creeks will be conveyed along the channel(s). Therefore, nearshore shallow areas are likely to represent worst-case conditions.

Faecally contaminated surface waters may result in settlement of contaminated silt being deposited in less flushed areas of the harbour and the lagoon. Furthermore, contaminants deposited onto the seabed can be returned to the water column via resuspension or diffusion processes.
Dredging operations may increase resuspension of contaminated sediments and promote the uptake of contaminants by bivalve molluscs. During the desk study of the sanitary survey, the Local Enforcement Authority identified that dredging work in Wells Harbour (Figure IV.6) could be a contributing factor for a high *E. coli* result (MPN = 16,000 $100g^{-1}$ FIL) in mussels from Wells Beacon in November 2009 (Claire Kinsley, North Norfolk DC, pers. comm.).

Figure IV.6 Dredging activities in Wells Harbour channel.
Photo courtesy Claire Kinsley (North Norfolk District Council).

APPENDIX V
HYDROGRAPHIC DATA: TIDES AND CURRENTS

GENERAL

The stretch of coast along the North Norfolk coast relevant to this survey is considered to be subjected to a semi-diurnal (two tidal cycles per day) macro-tidal regime. At Wells-next-the-Sea, the mean tidal range is 3.5m on spring tides and 2m on neap tides (Table V.1).

Table V.1 Tide levels and ranges in ports in the vicinity of the bivalve mollusc production area.

	Height (m) above Chart Datum			
Port	MHWS	MHWN	MLWN	MLWS
Overy Staithe	2.3	0.9	-	-
Wells Bar	6	4.8	-	-
Wells	3.5	2	-	-
Blakeney Bar	5.7	4.5	-	-
Blakeney	3.4	2	-	-

NB.Tidal level referred to Datum of soundings.
Data from Imray Chart Y9 - The Wash.

Tidal conditions along this stretch of coast are very variable due to different weather conditions, tidal effects and storm conditions (Funnell *et al.*, 2000; Adlard Coles Nautical, 2009). Offshore, tidal streams generally follow NW/SE direction in relation to the coastline (Adlard Coles Nautical, 2009).

The onshore movement of the waves runs parallel to the coast moving material along the beach (Frew, 2009). In addition, intense wave action brings sediment in the direction those waves will approach the shores (Frew, 2009). Wave energy in this area is lower in summer, whereas in winter high energy waves often erode the beach face and transport the sediment out to the nearshore zone (Frew, 2009).

WELLS-NEXT-THE-SEA

Tidal streams have been reported to reach 1.08m s^{-1} just East of Wells-next-the-Sea (May, 2007). This figure is within the range reported by Bayliss-Smith *et al*. (1979) based on field observations (0.5–1ms^{-1}). More recently, Lawrence *et al.* (2004) developed a hydrodynamic model for Stiffkey saltmarsh (approximately 5km East of Wells-next-the-Sea) and determined considerably lower averaged channel velocities in the upper saltmarsh (0.10–0.15ms^{-1}). The variation in tidal streams reported in these studies indicates that significant reductions may occur in nearshore tidal currents, in particular in the vicinity of saltmarsh. Furthermore, tidal flows will be stronger along the outer navigational channel than those over shallow flats along the inner harbour area.

From observations made during the shoreline survey, it seemed that rectilinear (back-and-forth) flows govern this navigational channel. Different paths were observed at The Pool, where wind driven currents will play a more significant role in resuspending sediment.

HR Wallingford Ltd was asked by Haskoning UK Ltd to provide advice relating to aspects of proposed dredging works to be carried out in the scope of the construction of a new Outer Jetty within Wells Harbour. As part of an assessment of the hydrodynamics resulting from the creation of dredged areas and construction of the jetty and pontoons, a TELEMAC-2D numerical flow modelling exercise was developed to simulate the pattern of tidal currents within the harbour.

Figures V.1a, b show the spring flood tide current vectors at half-hour intervals between 3.5hours before High Water (HW) and HW.

Figure V.1a shows that, during the early part of the second half of the flood tide, the incoming flow is confined to the low water channels. Between HW-3hours and HW-2.5hours, the flow inshore of the Lifeboat Station peninsula splits into two streams: one flowing through the Outer Jetty area and the other flowing up the main channel.

At HW-2hours, the flow offshore of the Lifeboat Station peninsula splits into two streams: one flowing past the peninsula and up to the main channel and the outer flowing to the East of Inner Bank.

Between HW-2hours and HW, the flow continues to be divided between setting inshore along the main channel and in an offshore direction to the East of Inner Bank. During the flood tide, a slow clockwise gyre is set up around Buxtons Bight to the South of the Lifeboat Station peninsula (HR Wallingford, 2009).

Figures V.1c, d show spring ebb tide current vectors at half-hour intervals between HW) and 3hours after HW.

During the early ebb tide (Figure VI.1c), the flow streams from the Inner Channel and The Fleets converge before moving North through the main channel, past the Lifeboat Station peninsula and out to either side of Inner Bank to join with the offshore West to east flow. During the latter part of the first half of the ebb tide (Figure IV.1d), the flow is confined to the low water channels.

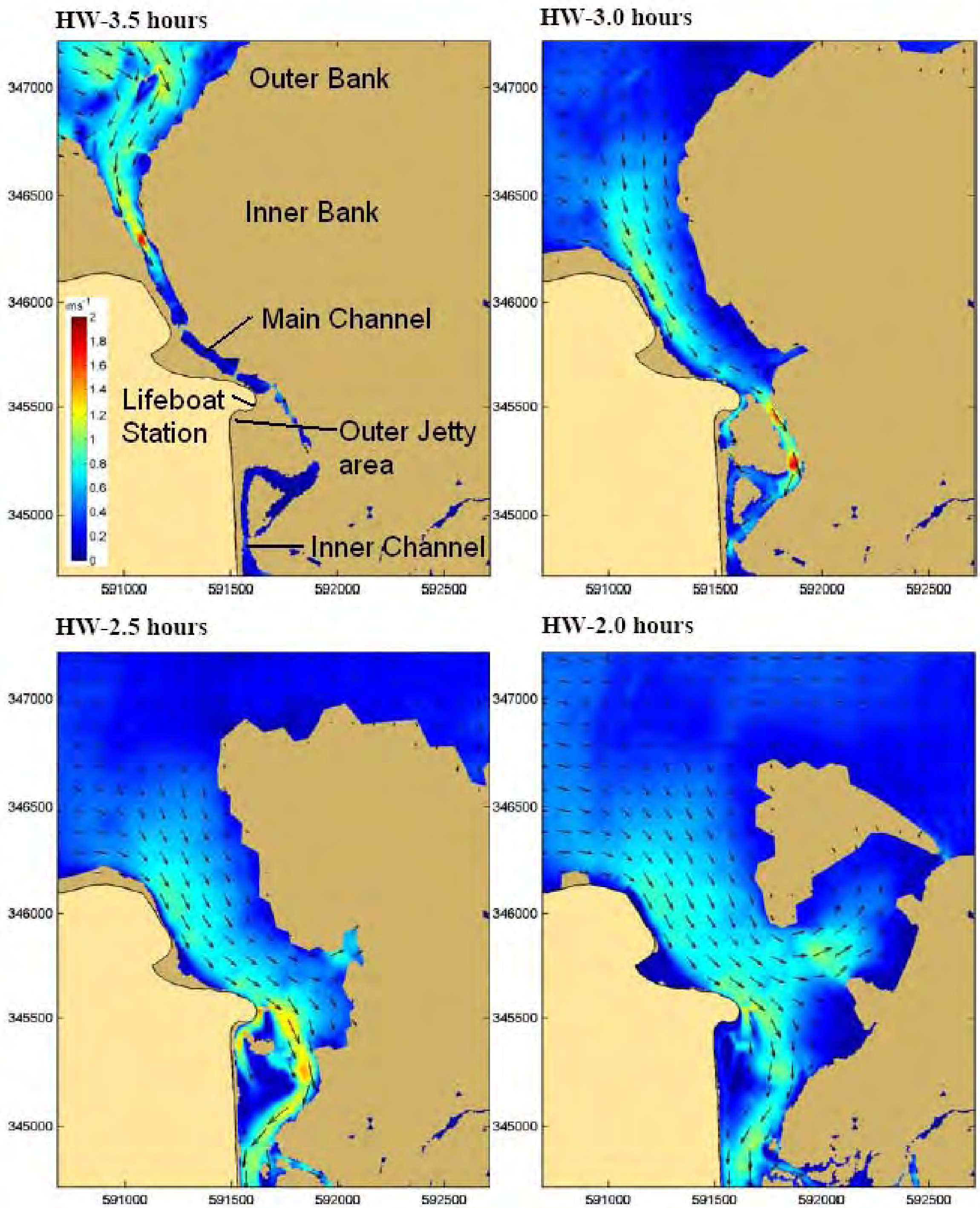

Figure IV.1a Spring tide current vectors between HW-3.5hours and HW-2hours.
Modified from HR Wallingford Ltd. (2009).

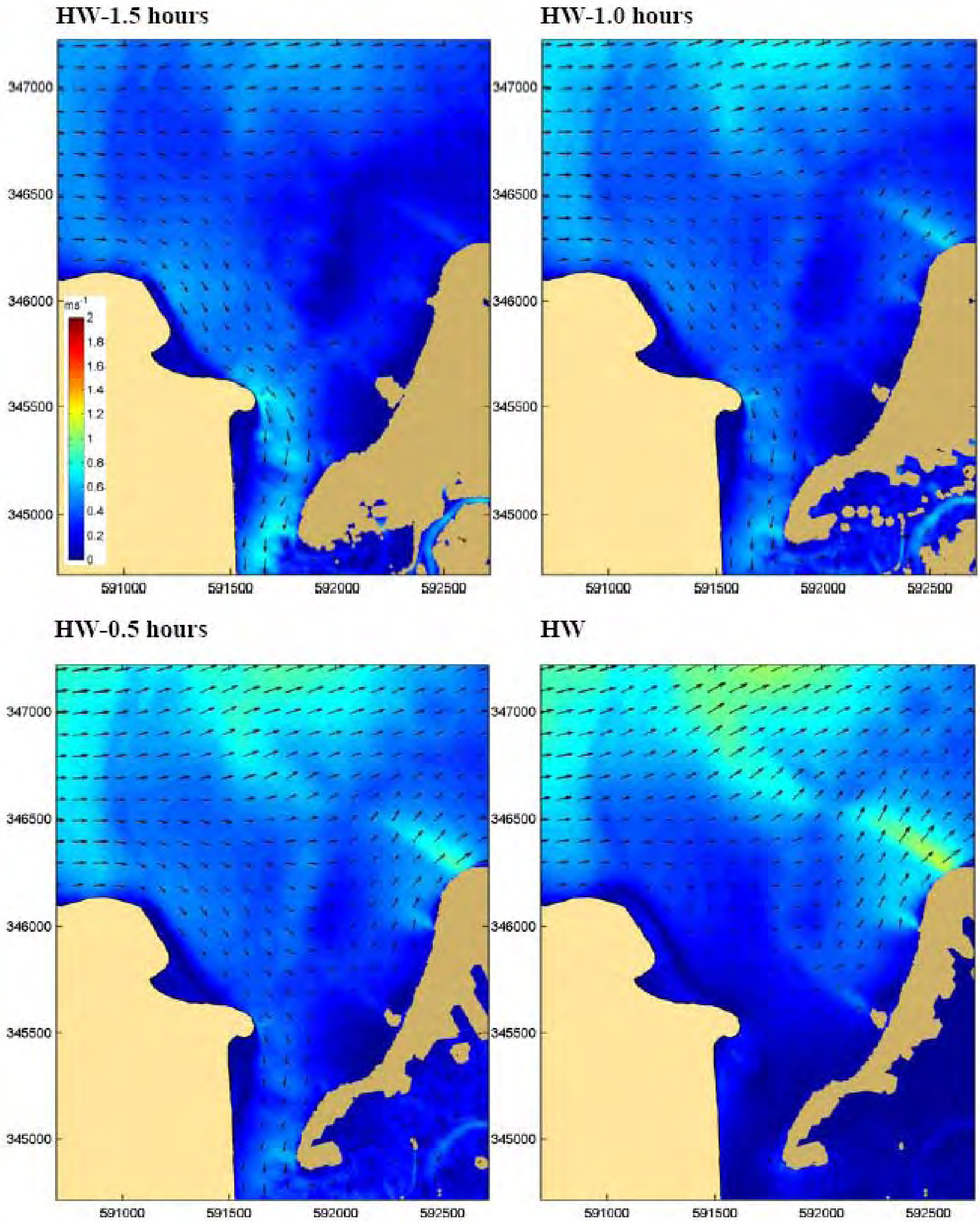

Figure IV.1b Spring tide current vectors between HW-1.5hours and HW.
Modified from HR Wallingford Ltd. (2009).

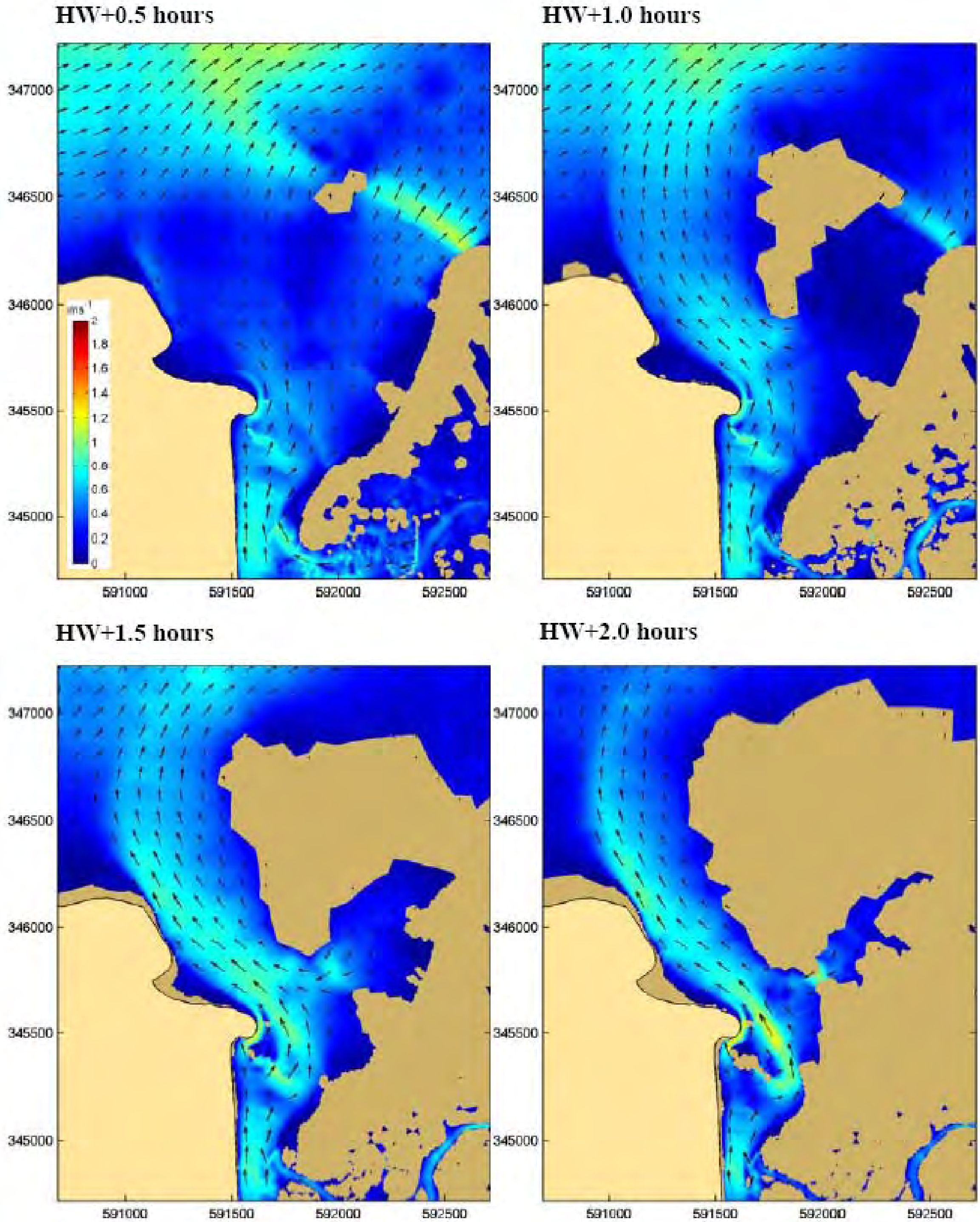

Figure IV.1c Spring tide current vectors between HW+0.5hours and HW+2hours.
Modified from HR Wallingford Ltd. (2009).

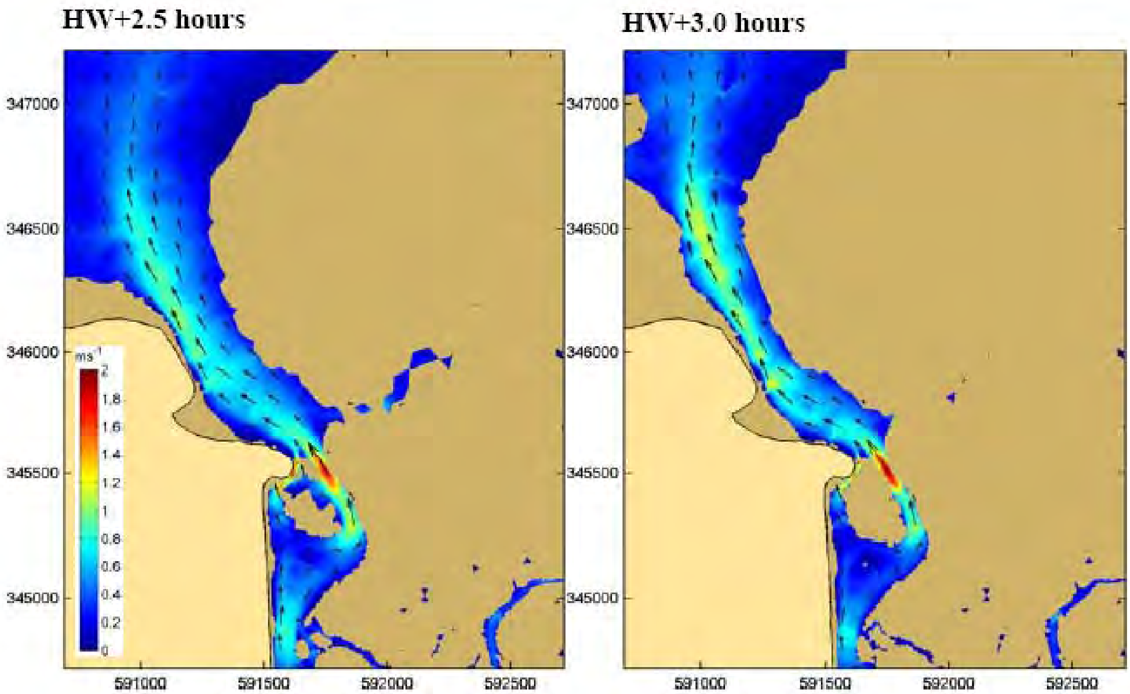

Figure IV.1d Spring tide current vectors between HW+2.5hours and HW+2hours.
Modified from HR Wallingford Ltd. (2009).

It is concluded that less flushed areas along the inner channel may promote entrainment of microbiological contamination from nearby pollution sources.

It is recommended that the representative monitoring point for mussels at Wells Harbour on the eastern edge of the proposed new bed in Wells Harbour since this area is thought to potentially represent the worst-case scenario of contamination.

Due to the small dimension of the bed at Wells Beacon, there is no opportunity to change the location of the representative monitoring point therefore a centroid location will adequately represent contamination across the whole bed. The information is however useful in informing assessments prompted by future initiatives to increase the extent of the mussel lays in this area.

BLAKENEY PERCOLATING LAGOON

In Blakeney Harbour, the Far Point receives large sand waves moving eastward from the Stiffkey intertidal sandbanks to the west during storm events (Royal Haskoning, 2002). However, there is significant wave attenuation provided by the saltmarsh. Möller *et al.* (1999) found that Stiffkey marshes account for over 60% of wave height reduction and that this if four times higher than that over sandflats.

Water exchange between Blakeney lagoon and the sea occur primarily through the Blakeney Channel. Near the mouth of the lagoon, mussel beds at Simpool Head are at the confluence of this channel and Freshes Creek and may therefore be impacted by pollution from the wider catchment discharged via the rivers

Stiffkey and Glaven. During the shoreline survey, it was noted that these shallow areas can be influenced by wind-driven currents.

A representative monitoring point situated on the eastern edge of the bed will best represent the effect of freshwater flows and also any contamination from wildlife (e.g. seals, seabirds) using the shallow sandflats.

Due to its proximity to Freshes Creek, the Pacific oyster bed at South Side (formerly designated Morston Strand) will be more impacted by pollution from the River Stiffkey. The small scale of the operation at Moston Strand means that a representative monitoring point situated in the centroid of the bed will adequately represent the whole bed.

APPENDIX VI
METEOROLOGICAL DATA: WIND PATTERN

The strongest winds are associated with the passage of deep depressions and the frequency and strength of these is greatest in the winter (Met Office, 2007). As Atlantic depressions pass England and Wales, the wind typically comes from the west or northwest as the depression moves away. For this reason, the Eastern England region is less exposed to wind effects. A wind rose for Coltishall (approximately 40km from Blakeney) shows that the prevailing wind direction is from the south-west and that the strongest winds nearly always blow from the range of directions West-Southwest (Figure VI.1).

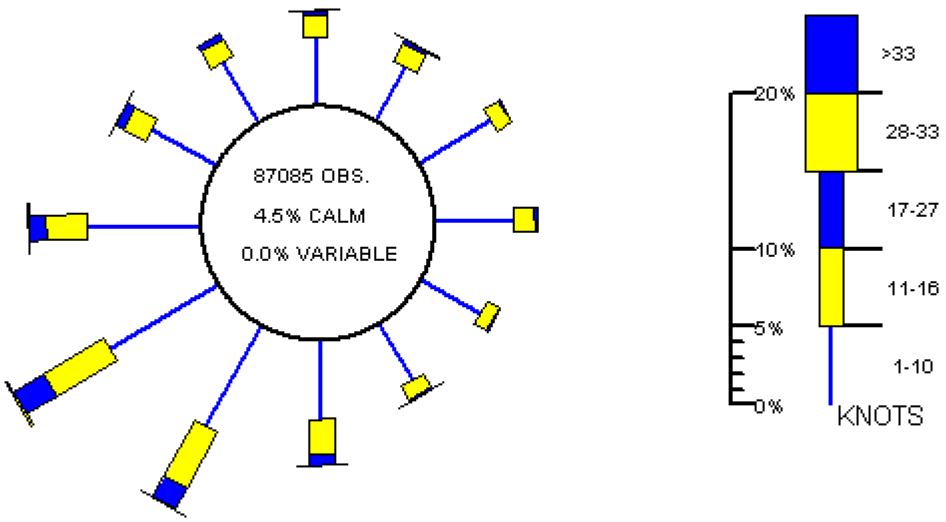

Figure VI.1 Wind rose for Coltishall, Norwich (Norfolk).
NB.Grid reference of station: Easting/Northing (6262/3229), altitude=17m.
Period of data: January 1995–December 2004.
Modified under permission by the Met Office.

The north facing aspect of the North Norfolk coast sheltered from the predominantly westerly winds means that, during most of the time, surface water flows affected by the wind will promote the seaward transport of contamination during the ebb stage of the tide. Given that this stretch of coast is unlikely to be at risk of microbiological contamination from seaward, representative monitoring points situated in inshore areas will best reflect the cumulative effect of the dominant sources of pollution in Wells Harbour and Blakeney lagoon.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

The locations of sewage discharges that are potential sources of microbiological contamination to bivalve molluscs at Wells-next-the-Sea and Blakeney are shown in Figure VII.1.

Sewage effluents in catchments draining to Wells-next-the-Sea and Blakeney are treated in a number of sewage treatment works (STWs), the larger ones associated with the urbanised areas of Wells-next-the-Sea, Stiffkey, Blakeney and Cley next the Sea.

Of those Anglian Water company continuous discharges identified in the Environment Agency Pollution Reduction Plan as having a significant or potentially significant impact on the designated Shellfish Water, only Wells-next-the-Sea STW discharges directly to Wells Harbour. Cley-next-the-Sea STW and Stiffkey STW discharge to the rivers Glaven and Stiffkey, respectively (Figure VII.1).

The sewerage infrastructure is also served by a number of combined sewer overflows (CSO), emergency overflows (EO) and overflows from sewage pumping stations (PS). Of particular significance to bivalve mollusc beds are two CSOs discharging to Wells harbour and several pumping stations potentially impacting on the Morston Strand and Simpool shellfisheries (Figure VII.1).

Intermittent sewage discharges can deliver highly contaminated water to coastal areas resulting from the rapid flushing of stored contaminants during storm conditions and/or the overloading during periods of heavy rainfall (Lee *et al.*, 2003 and references therein). Contaminant microorganisms in these discharges can be rapidly accumulated by bivalves and be the cause for the deterioration in the microbiological quality of many BMPAs (Younger *et al.*, 2003).

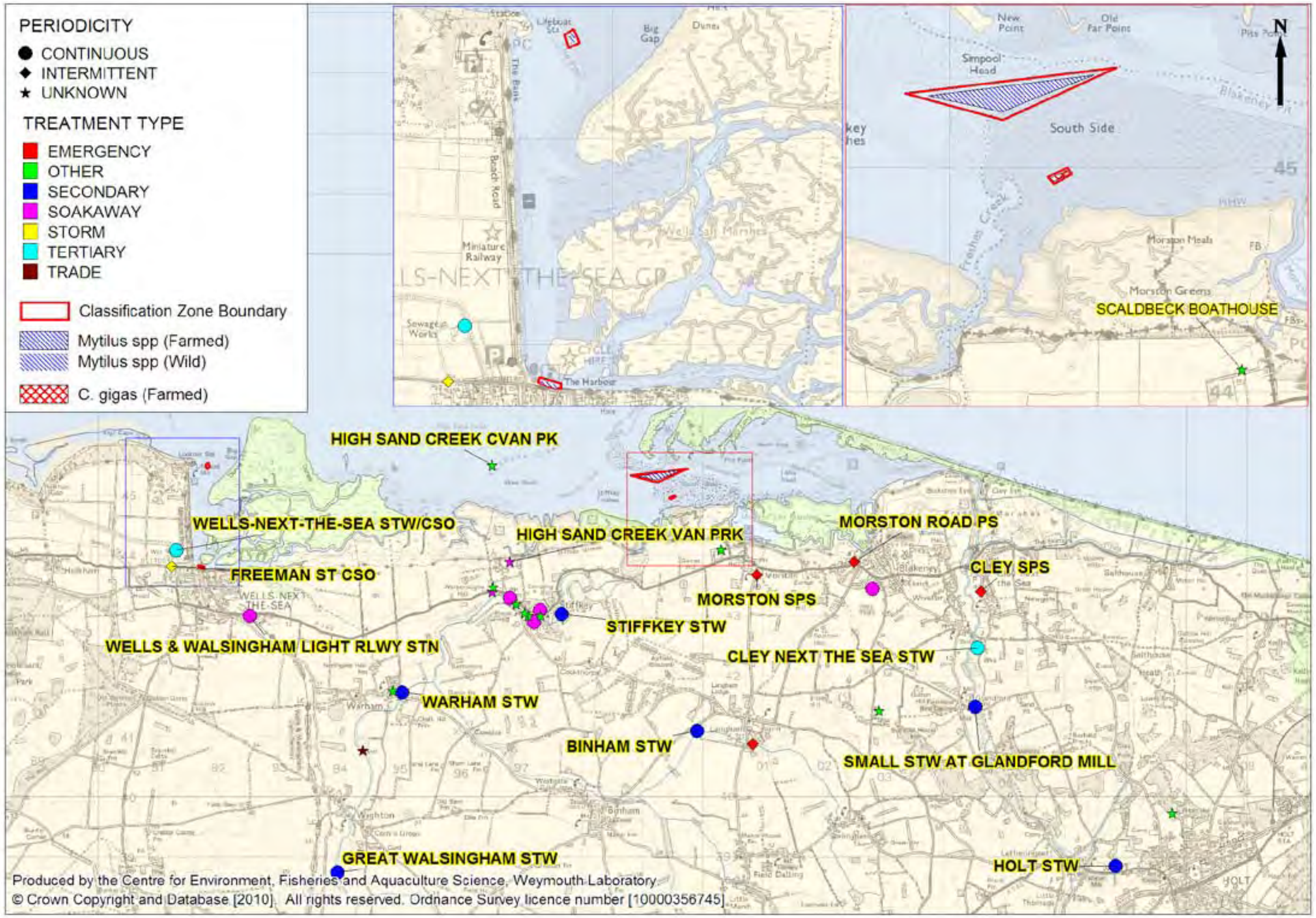

Figure VII.1 Location of significant sewage discharges to Stiffkey and Glaven catchments.

Table VII.1 Significant water company continuous sewage discharges to Wells Harbour and Blakeney.

Name	Treatment	DWF m^3 day^{-1}	Population equivalent	NGR of the outfall	Fluvial distance to nearest BMPA (km)
Wells-next-the-Sea STW	UV disinfected	1,125	7,249	TF 91280 44080	0.56
Cley-next-the-Sea STW	UV disinfected	650	2551	TG 04540 42470	8.24
Stiffkey STW	Secondary	14	68	TF 97660 43030	3.36

Data compiled from Cefas database and Environment Agency (2009).
DWF - dry weather flow.
STW - sewage treatment works.

The most significant Anglian Water company continuous discharge potentially impacting on the proposed mussel bed in Wells Harbour is Wells-next-the-Sea sewage treatment works (STW). This UV disinfected effluent discharges approximately 500m from the new mussel beds (Table VII.1) and approximately 1.9km from the current mussel beds, Wells Beacon, located at the mouth of the main navigation channel into Wells Harbour. In general it is considered that for most of the time the contribution of tertiary treated effluents as sources of microbiological contamination impacting on BMPAs is low when compared with other sewage discharges or sources of contamination of diffuse origin.

Warham STW, Great Walsingham STW and Binham STW discharge into the River Stiffkey several km upstream of the town of Stiffkey, so will contribute to overall microbiological loadings to the River, but are not seen as significantly impacting on the shellfisheries.

Further east along the coast, the secondary treated effluent from Stiffkey STW discharges to the River Stiffkey approximately 3.36km from the edge of the oyster bed at Morston Strand. Cley-next-the-sea STW discharges into the River Glaven >8km from Morston Strand shellfish bed. This discharge receives UV disinfection.

Other STWs upstream in the River Glaven catchment include a small STW at Glandford Mill which discharges to land. Holt STW is larger, but it is over 12km from the nearest shellfish beds. Neither of these discharges is thought to significantly impact on the shellfisheries at Blakeney.

Table VII.2 Significant water company intermittent sewage discharges to Wells Harbour and Blakeney.

Name	Type	NGR of the outfall	Fluvial distance to nearest BMPA (km)
Wells-next-the-Sea STW SO	Storm	TF 91280 44080	0.56
Freeman St. CSO	Storm	TF 91200 43820	0.44
Cley SPS	Emergency	TG 04600 43400	7.26
Morston SPS	Emergency	TG 00890 43680	2.79
Morston Road PS	Emergency	TG 02500 43900	4.41

Data compiled from Cefas database and Environment Agency (2009).
DWF - dry weather flow.
STW - sewage treatment works.
CSO - combined sewer overflow.
SO - storm overflow.

There are two intermittent storm discharges with the potential to impact on shellfisheries on both the proposed mussel bed in Wells Harbour and the existing bed at Wells Beacon: the storm overflow from Wells-next-the-sea STW and Freeman St CSO. Spill summary data for these storm overflows is given in Table VII.3. This data shows that for most years spill frequencies and volumes are relatively low, except 2007 during which Freeman Street CSO storm overflow was in operation for >62 hours[7].

There are three pumping stations with the potential to impact on Blakeney shellfisheries: Cley SPS, Morston SPS and Morston Road PS. Emergency discharges of crude sewage from these could cause microbiological contamination in their receiving waters and potentially in the shellfisheries.

Table VII.3 Numbers of spills per year recorded at monitored storm overflows to Wells Harbour (Data supplied by the Environment Agency)

Site	Number of spill events				Duration (hours/mins)			
	2006	2007	2008	2009	2006	2007	2008	2009
Wells-next-the-sea STW CSO	3	12	3	2	14.15	1.45	3.00	0.30
Freeman Street CSO	12	3	5	2	0.40	62.55	0.00	2.01

In terms of other non-water company discharges, Wells and Walsingham Light Railway Station is located to the south of Wells Harbour discharges to a soakaway and is approximately 1km south-east of the harbour. Therefore, for the purposes of this assessment, the impact of this discharge is considered to be minimal.

In the town of Stiffkey there are several small discharges from domestic properties which, when combined, could contribute to microbiological loading into the River Stiffkey (Figure VII.1). They discharge between 4.86km and 3.95km from Morston Strand BMPA.

There are two discharges near Stiffkey associated with High Sand Creek Caravan Park: one from a septic tank discharging to land and the other a pipeline discharge of an unknown treatment type into Cabbage Creek.

There are various other discharges from farms in the catchment, but all are either onto land, to groundwater or to soakaways, the nearest of these being approximately 1.2km south of the harbour. As such, these are not perceived as having the potential to impact on the BMPA.

Table VII.4 presents summary statistics for levels of faecal coliforms quantified in final effluent discharges from Wells-next-the-Sea STW and Cley next the Sea STW. Maximum levels of the microbiological indicator indicate the existence of periods when the quality of the final effluent had deteriorated in both sewage works.

[7] During the consultation stage of the survey, the Environment Agency informed Cefas that the 62 hour discharge from Freeman Street CSO was caused by a one off sewer blockage.

Table VII.4 Summary statistics of presumptive levels of faecal coliforms in the final effluent post UV disinfection monitored in two sewage treatment works.

		CFU Faecal coliforms 100ml^{-1}			
Name	Period	Number of samples	Geometric mean	Minimum	Maximum
Wells-next-the-sea STW	September 1999–December 2005	148	260	5	730,000
Cley next the Sea STW[8]	October 2000–December 2005	124	1,196	1	2,000,000

Side-by-side box-and-whisker plots of levels of *E. coli* grouped by season (Figure VII.2) show periods of deteriorated quality of final effluent discharges from Wells-next-the-Sea STW (summer–autumn) and from Cley next the Sea (spring–autumn).

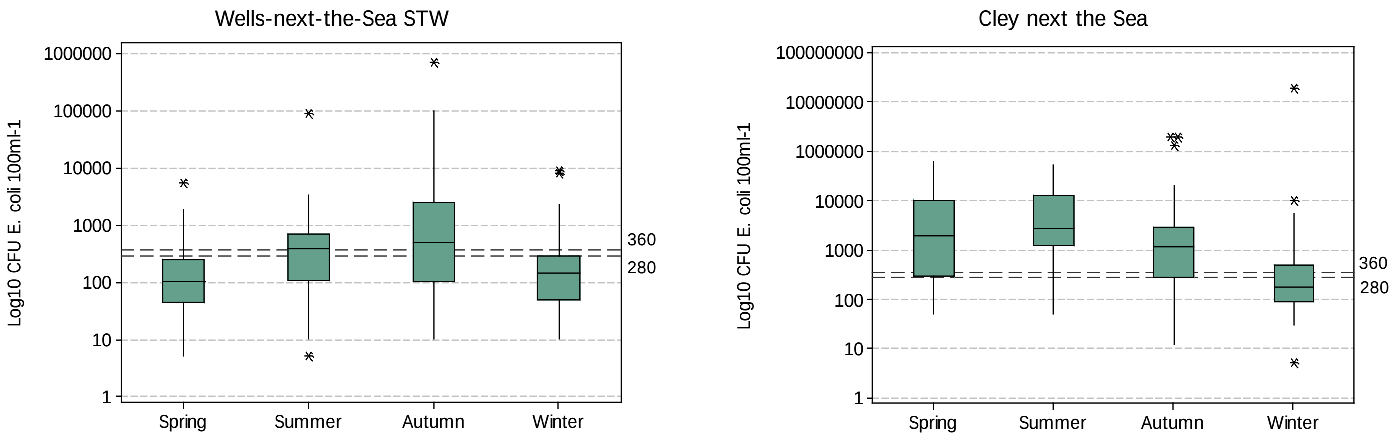

Figure VII.2 Box-and-whisker plots of seasonal levels of* E. coli *in the final effluent post UV disinfection monitored during the period September 1999–December 2005 in sewage treatment works discharging to Wells Harbour and Blakeney.

N.B. Spring: March–May; Summer: June−August; Autumn: September−November; Winter: December−February.

Reference lines correspond to typical levels of faecal coliforms in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents by Kay et al. (2008).

Statistically significant differences (Kruskal-Wallis test[9]: H = 19.58; p = 0.000) were found between the levels of *E. coli* in the autumn relative to those in the winter in effluent discharges from Wells-next-the-Sea STW. Similarly, one-way Analysis of Variance (ANOVA) with Tukey HSD post-hoc test (95% confidence level) revealed statistically significant differences ($F_{3,199}$ = 6.20; p=0.001) between levels of the microbiological indicator in the summer and those in the winter from Cley next the Sea STW.

[8] During the consultation stage of the survey, the Environment Agency informed Cefas that the quality of effluent discharges from Cley next the Sea has improved in recent years (geometric mean: 177 in 2007, 160 in 2008 and 300 in 2009) and that Wells-next-the-Sea STW has maintained good performance in recent years.

[9] Datasets were found to be not normally distributed and therefore the assumptions of parametric analysis of variance were violated.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Agricultural land covers the vast majority of the river catchments assessed in this sanitary survey. Approximately 73% of the agricultural area in the North Norfolk Local Environment Plan Area is in arable rotation for cereals (wheat and barley, etc.) and break crops (e.g. potatoes, sugar, field beans and peas, etc.). Grassland for livestock production represents less than 10% of the total agricultural area (Environment Agency, 1996). Arable and horticulture represent 78% of the land in the Stiffkey catchment (NERC-CEH, 2009).
High numbers of farms occur in the upper reaches of catchments draining to the Rivers Stiffkey and Glaven (Figure VIII.1).

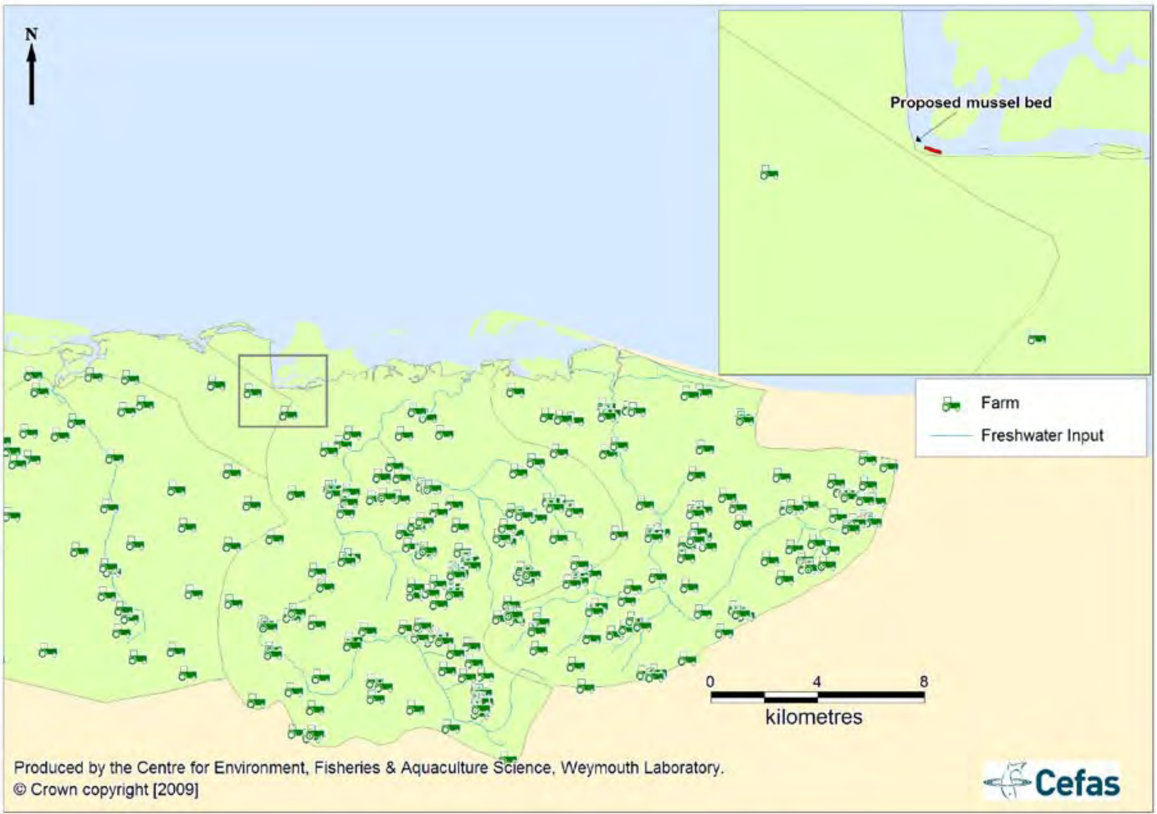

Figure VIII.1 Farms in catchments draining to rivers Stiffkey and Glaven.

Most of the livestock in catchments draining to Wells Harbour and Blakeney Spit Pools are poultry. Cattle and sheep represent only 2% of the total livestock in these river catchments (Table VIII.1).

Table VIII.1 Livestock numbers in catchments draining to Wells Harbour and Blakeney Spit Pools.

Catchment	Cattle	Pigs	Sheep	Poultry	Other livestock
Burn	333	*	1,591	418	26
Glaven	1,467	11,910	919	160,573	127
Hun and Coast	*	*	*	*	*
Stiffkey	2,279	3,385	4,975	352,401	106

Data from June Agricultural Survey 2008 (Defra Farming Statistics, 2010).
*No data shows *.*

Farmyards can significantly contribute to loads of faecal indicator microorganisms to watercourses or coastal waters when they have a ready and renewable source of faecal material, a direct hydrological connection with open water channels exists and a sufficient proportion of livestock farms are present in the catchment (Edwards *et al*., 2008).

The concentration of faecal coliforms excreted in the faeces of these animal species and humans and corresponding daily loads are summarised in Table VIII.2.

Table VIII.2 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Farm Animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^{8}
Cow	230,000	23,600	5.4×10^{9}
Pig	3,300,000	84,000,000	8.9×10^{8}
Sheep	16,000,000	38,000,000	1.8×10^{10}
Human	13,000,000	3,000,000	1.9×10^{9}

Data from Geldreich (1978) and Ashbold et al*. (2001).*

The absence of significant freshwater inputs to Wells Harbour and Blakeney Spit Pools and the low numbers of cattle and sheep in the catchments indicates low risk of diffuse pollution from livestock production areas.

In 2007, a source apportionment model for faecal indicator microorganisms (FIO) was developed by ADAS, CREH and IGER. The model aimed to determine the contribution of agriculture to FIO loadings impacting designated bathing and shellfish waters in various coastal catchments with mixed land uses in the UK during the bathing season. Blakeney was one of the selected catchments due to failing Shellfish Waters. This catchment had previously been considered by the Environment Agency to be affected by diffuse pollution.

The model predicted a higher geometric mean concentration of faecal coliforms from urban sources of pollution than those from rural sources under high river flow conditions in this catchment. This result is particularly relevant for the purposes of selecting locations for representative monitoring points (RMPs), suggesting that RMPs in close proximity to sewage discharges in the urban area will best reflect the cumulative effect of these sources.

APPENDIX IX
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BOATS

Wells-next-the-Sea and Blakeney harbours are very popular for a variety of activities including sailing, wind-surfing, water skiing and occasional use of canoes, kayaks, speed boats, cruising yachts and large motor cruisers.
A sailing club, sailing school and a water ski club operate from Wells-next-the-Sea. Jet-skiing and hovercrafting are not permitted within harbour limits.

There is a small fishing fleet of 11 vessels in Wells-Next-The-Sea harbour, with occasional visiting fishermen from neighbouring ports (Wells Harbour, 2009).

Figure IX.1 shows the location of slipways and moorings in Wells Harbour in relation to the proposed mussel bed.

Figure VIII. Location of slipways and moorings along part of the North Norfolk coast from Wells to Blakeney (inset).

In Google Earth, over 70 boats could be seen from the harbour mouth through to the inner harbour. Several hundred more can be seen on the shoreline and in the quayside compound.

Wells Harbour has seen an increase in the number of visiting and leisure vessels. There are 200 long-stay moorings, as well as several areas designated for fishing boats and other vessels (Wells Harbour, 2009).

Marinas and ports have historically been identified as major sources of faecal contamination (see Sobsey *et al*., 2003). This is based on the assumption that some boat owners will, at some time, illegally discharge their head (onboard toilet) into harbour waters. An assessment of the potential impact of sewage discharges from boats and marinas on the microbiological status of BMPAs requires detailed quantitative information on boat movements, occupancy rates and seasonality and accurate knowledge on dilution of contaminants in receiving waters. Undertaking such assessment falls outside the scope of the sanitary survey.

The EA Pollution Reduction Plan pointed out that emissions from moored boats may contribute to faecal indicator organism (FIO) load in or near the designated Shellfish Water and that an investigation into causes and solutions for localised FIO pollution would be useful (Environment Agency, 2008).

There is a sewage pump-out facility in Wells Harbour (Wells Harbour, 2009) will minimise the risk of pollution from boats. Under the Harbour Master's Directions for use of Wells Harbour, no oil, bait, rubbish, sewage or any other substance is allowed to enter into the harbour, and any accidental spillage reported immediately. Vessels with direct discharge toilets must seal off exit ports, and any persons causing pollution may be subject to a fine (Wells Harbour, 2009). The control of pollution into Wells Harbour is reinforced by the Special Area of Conservation (SAC) designation in the area.

A representative monitoring point in the newly proposed mussel bed should monitor any sewage discharged from boats in Wells Harbour. Similarly, an RMP situated in inner areas of Blakeney lagoon will monitor contamination from these sources.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

BIRDS

The North Norfolk coastline provides a diversity of natural habitats for large communities of birds and colonies of seals (Figure X.1).

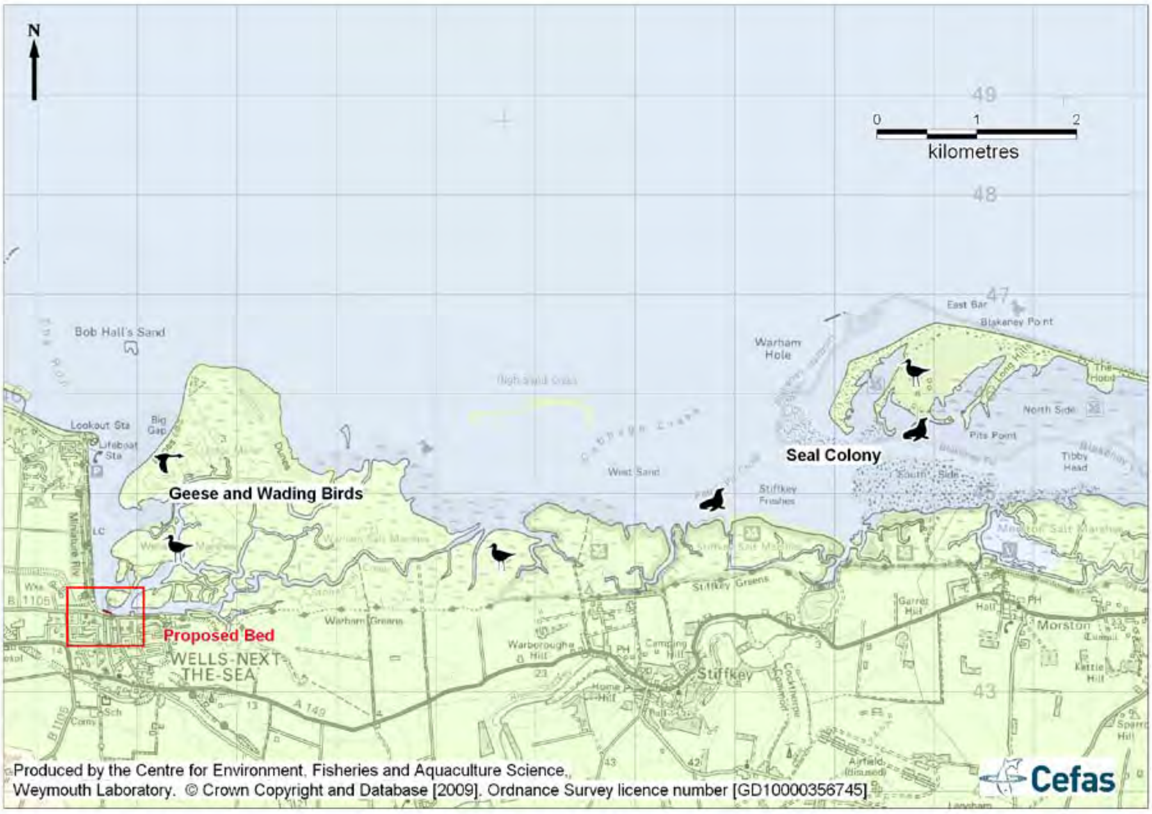

Figure X.1 Location of bird and seal colonies along the coast of North Norfolk, between Wells-Next-The-Sea and Blakeney.

In the summer breeding season, Wells-next-the-Sea supports large populations of Terns, Oystercatchers, Cormorants, Starlings and Turnstones. In the winter, birds such as Brent geese and Pink-footed geese over-winter in the harbour. Mallards and Mute swans can be found in this area year round.

Low tide counts for waders, gulls and waterfowl were undertaken in Wells Harbour by the BTO/WWT in 2008–2009 under the scope of the Wells Channel Deepening and Jetty project. Counts were made from a series of vantage points frequently from more elevated positions such as the seawall, the Lifeboat House and higher sandbanks along the main navigational channel edge.

Tables X.1–X.2 list counts of some of the most significant bird species in the vicinity of Wells Harbour.

Table X.1 Total bird counts in Wells Harbour.

Species	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09
Lifeboat House					
Brent Goose	85	3	8	0	24
Dunlin	27	4	9	12	47
Curlew	6	5	6	6	10
Bar-tailed Godwit	17	31	1	7	0
Redshank	36	18	12	17	9
Knot	27	0	0	0	8
Turnstone	27	8	5	15	2
Sanderling	0	0	0	0	0
Grey Plover	14	8	3	8	5
Lapwing	158	1,040	0	0	0
Ringed Plover	1	14	5	19	5
Shelduck	0	0	0	1	2
Goldeneye	0	0	5	0	0
Oystercatcher	267	20	17	26	41
Main channel					
Brent Goose	152	23	27	169	10
Dunlin	37	375	46	146	44
Curlew	14	5	20	16	9
Bar-tailed Godwit	168	93	55	122	31
Redshank	43	64	40	39	38
Knot	1,510	1,932	0	6	424
Turnstone	44	19	44	77	29
Sanderling	46	32	131	30	118
Grey Plover	16	43	32	31	46
Lapwing	0	0	0	0	0
Ringed Plover	0	42	37	71	2
Shelduck	0	23	23	0	0
Goldeneye	0	0	0	0	0
Oystercatcher	146	30	118	376	445

Data from Bishop and McCullen (2009).

Table X.2 Seabird counts in Wells Harbour.

Species	**Common name**	**Total count**	**Count type**
Larus argentatus	Herring Gull	294	Occupied nests
Larus canus	Common Gull	6	Occupied nests
Larus fuscus	Lesser Black-backed Gull	226	Occupied nests
Larus melanocephalus	Mediterranean Gull	2	Occupied nests
Larus ridibundus	Black-headed Gull	2,336	Occupied nests
Sterna albifrons	Little Tern	170	Occupied nests
Sterna hirundo	Common Tern	108	Occupied nests
Sterna paradisaea	Arctic Tern	4	Occupied nests
Sterna sandvicensis	Sandwich Tern	75	Occupied nests

Data from Seabird 2000 database.

Various key feeding areas were identified during the survey. In the main channel, the most important were the mudflats and stony ground East of the Lifeboat House, the wet, low-lying sandflats along the East side of the channel, areas East of navigational buoys on the edge of the channel and higher shingle ridges to the East of the main channel and in *Zostera* beds (Bishop and McCallum, 2009). In the South of the Lifeboat House, the preferred feeding areas were the muddy flat and a small tidal channel (Bishop and McCallum, 2009). Figure X.2 shows distribution maps for four of the most representative species in Wells Harbour.

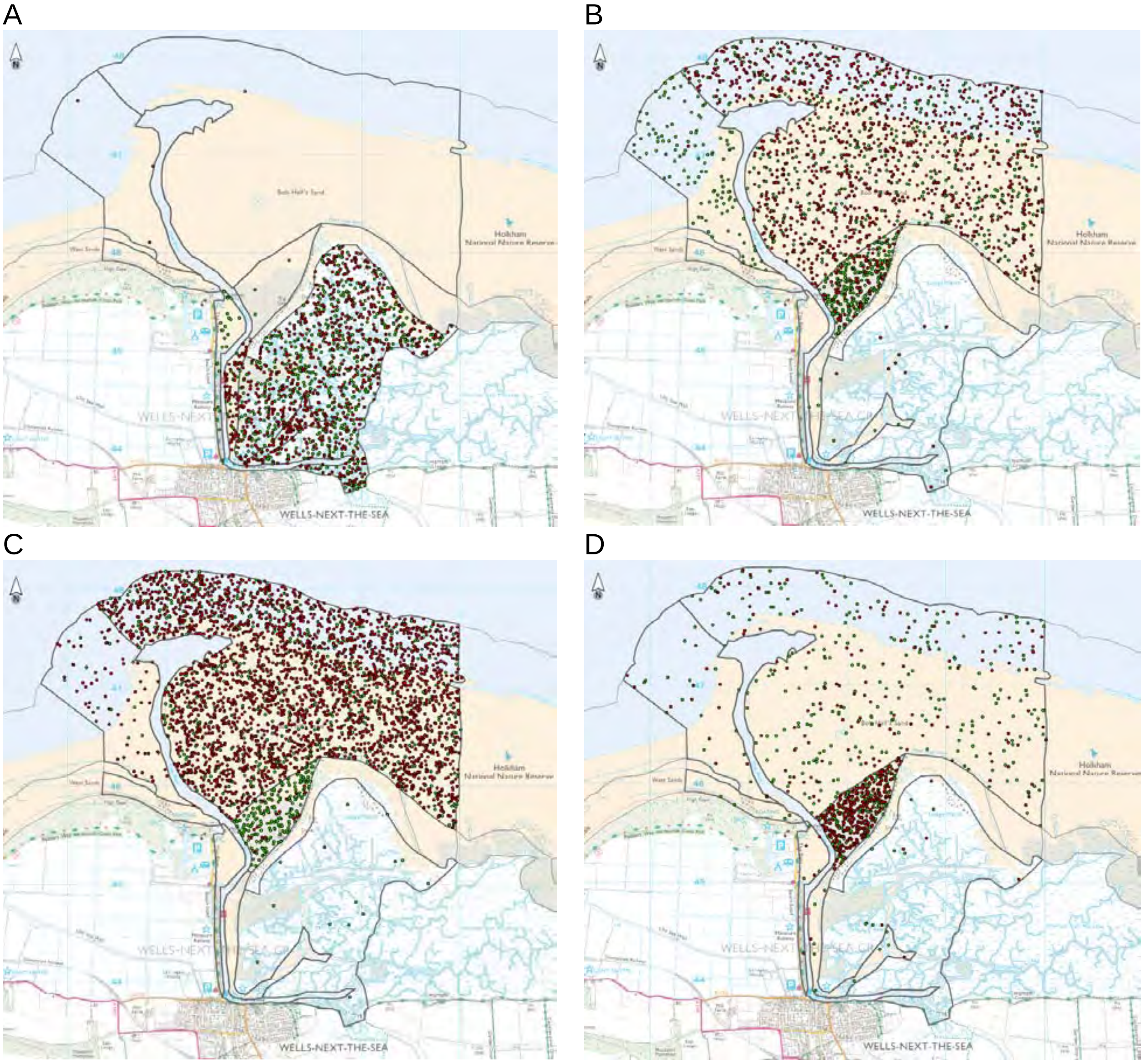

Figure X.2 Distribution of four representative species of birds in Wells Harbour. A - Dark Bellied Brent Goose, B - Dunlin; C - Knot; D - Oystercatcher.
Data from Wells Harbour channel deepening and jetty construction.

Previous studies in the UK have indicated significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). For example, geometric means of *E. coli* detected in faecal samples of Starling (*Sturnus vulgaris*) can be 4.6×10^{7}CFU $100g^{-1}$ (Environment Agency, 2003; Whither *et al*., 2003). Feare (2001) suggests that approximately 10% of the faecal matter could be deposited under a roost, suggesting the potential significant contribution of contamination in these areas.

Due to the high numbers of over-wintering birds in the area, winter may be a time of increased microbial contamination from birds. This is particularly important in the area of mudflat and saltmarsh to the East of the harbour mouth. Microbial pollution from birds may be washed into the harbour during the flood tide.

SEALS

In addition to the large bird populations in and around Wells Harbour, there is also a large population of grey and common seals approximately 10km to the east at Blakeney Point. The Point is generally used as a haul-out for the seals, although a few do use the area to pup. Seal numbers in the area peak during August and early September when the seals are moulting (Wood, 2009). Seal numbers are estimated to be around 500, with common seals having pups from June to August, and grey seals form November to January (Beans Boat Trips, 2009).

The EA Pollution Reduction Plan recommends that an investigation on the influence of the seal population on the water quality in Blakeney would be useful to tackle diffuse pollution problems and improve water quality in Blakeney. A microbial source tracking study was proposed by the EA to clarify potential sources of contamination in this area. This study is due to be completed in 2010. Although scientific literature has indicated that seal faeces could represent a significant source of faecal contamination to coastal waters (see Hughes and Thompson, 2003; Lisle *et al.*, 2004; Stewart *et al.*, 2008), most of the studies to date have been undertaken in near pristine environments. For the purposes of this assessment, it is considered that RMPs situated in the confluence of low water channels will adequately represent any contamination from bird and seal populations using Wells Harbour and Blakeney lagoon.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

SHELLFISH WATERS

The sandflat from West Sands at Wells-next-the Sea to the western part of Blakeney Harbour is designated under Directive 2006/113/EC as Blakeney Shellfish Water (Figure XI.1).

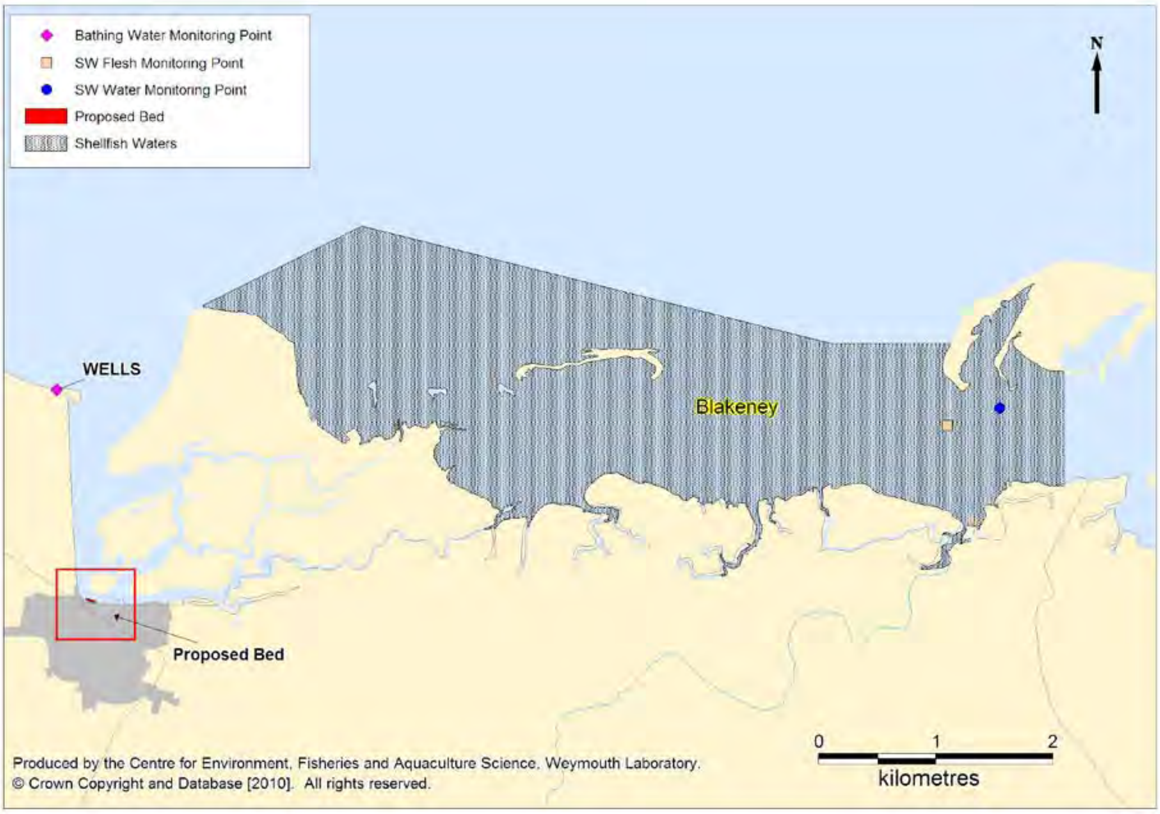

Figure XI.1 Location of designated Bathing water and Shellfish water and associated monitoring points in Blakeney and Wells-next-the-Sea.

Table XI.1 shows summary statistics for levels of faecal coliforms in this shellfish water for the period January 2000–December 2008.

Sampling effort decreased significantly during the monitoring period. Maximum levels of the microbiological indicator in 2001 and 2004 suggest that in the past, water in the lagoon had periods of deteriorated quality. The low number of samples analysed in recent years limits an assessment as to whether periods of high contamination have occurred in recent years.

Table XI.1 Summary statistics of faecal coliforms in Blakeney designated Shellfish Waters for the period January 2000–December 2008.

		CFU Faecal coliforms 100ml^{-1}			
	Number of samples	Minimum	Maximum	Geometric mean	Median
2000	12	10	827	71	86
2001	12	10	4,500	84	55
2002	12	10	280	36	36
2003	9	5	510	31	18
2004	3	21	6,000	245	117
2005	3	1	36	11	36
2006	5	5	140	41	128
2007	5	2	74	17	29
2008	4	6	554	40	29

Data from the Environment Agency (2009).

BATHING WATERS

Wells-next-the-Sea has a bathing water (BW) designated under Directive 76/160/EEC (European Communities, 2006)[10]. This is located approximately 1.8km from the proposed mussel bed at Wells Harbour (Figure XI.1).

The overall quality of the BW for the period 1999–2009 is summarised in Table XI.1. This bathing water has achieved 'Good' and 'Excellent' overall classifications during this period.

Table XI.1 Quality of the designated bathing water at Wells for the period 2000–2009.

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Excellent	Good	Excellent	Excellent	Good	Excellent	Good	Excellent	Excellent	Excellent

Data from the Environment Agency (2009).

Table XI.2 summarises sampling effort, range, geometric mean and median of faecal coliforms in surface waters during the period 2000–2009.

There were no results above the "Imperative" level detected during this period. With the exception of 2008, median and geometric mean values have been relatively low indicating low levels of microbiological contamination seaward of Wells Harbour area during the bathing season.

[10] The bathing season runs from 15 May to 30 September. Water is sampled throughout the season. Levels of bacteria must not exceed the Imperative (I) value (2,000 faecal coliforms 100ml^{-1}) and the Guideline (G) value (100 faecal coliforms 100ml^{-1}) represents the ideal maximum value. Bathing waters in England and Wales are classified as:
Poor - fails at least one coliform I standard;
Good - passes coliform I standards but fails at least one coliform G standard;
Excellent - passes coliform G standard and faecal streptococci standards.

Table XI.2 Summary statistics of faecal coliforms in Wells-next-the-Sea designated Bathing Water for the period 2000–2009.

	Number of samples	Minimum	Maximum	Geometric mean	Median
2000	20	<10	480	21	18
2001	20	<10	1,436	15	5
2002	20	<10	130	14	5
2003	20	<2	220	12	12
2004	20	<2	1,360	15	12
2005	20	<2	308	15	22
2006	20	<2	423	14	18
2007	20	<2	577	20	18
2008	21	<2	385	33	50
2009	20	<2	484	22	18

Data from the Environment Agency.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Table XII.1 shows summary statistics for levels of *E. coli* in bivalves from six representative monitoring points (see Figure 2.1) in Blakeney obtained under the scope of the Shellfish Hygiene monitoring programme during the period January 2000–June 2009.

Results suggest the following relationships in levels of contamination between beds:

- Wells Beacon>Simpool (mussels);
- Stiffkey≈Wells Beacon (cockles);
- Freshes Creek>Morston Strand (Pacific oysters).

It should be noted that these relationships are merely indicative of the overall microbial quality of bivalves at these sites since monitoring periods have varied considerably over the monitoring period.

One result above the class C threshold (MPN≤46,000 *E. coli* $100g^{-1}$ FIL) and the highest median and geometric mean in mussels from Wells Beacon indicates that this site is vulnerable to episodes of deteriorated microbial quality.

In contrast, the lowest levels of contamination were detected in mussels at Simpool, indicating that this area is currently the less contaminated site of the BMPA.

Table XII.1 Summary statistics for levels of* E. coli *in bivalves from six representative monitoring points in Blakeney for the period January 2000–June 2009.

							MPN *E. coli* 100g^{-1} FIL							
RMP	Bed name	Species	n	Date of first sample	Date of last sample	Min.	Max.	Median	Geometric mean	Coefficient of skewness	[11]Kurtosis[12]	Log_{10} St. Dev	Lower	Upper
B006C	Simpool	*Mytilus* spp.	110	10/01/2000	08/06/2009	<20	16,000	70	105	5.90	38.14	0.77	76	146
B006I	Stiffkey	*C. edule*	93	10/01/2000	16/04/2007	<20	24,000	500	421	4.13	19.02	0.77	294	604
B006K	Morston Strand	*C. gigas*	81	11/11/2002	08/06/2009	<20	9,100	265	222	4.55	24.39	0.68	159	311
B006L	Freshes Creek	*C. gigas*	36	02/12/2002	08/05/2005	<20	9,100	550	584	2.15	3.98	0.70	340	1,004
B006N	Wells Beacon	*Mytilus* spp.	71	06/01/2004	08/06/2009	40	54,000	700	713	7.53	61.47	0.58	526	966
B006O	Wells Beacon	*C. edule*	55	24/03/2004	09/02/2009	<20	16,000	500	442	3.82	15.13	0.68	293	668

[11] The coefficient of skewness measures the degree of symmetry in the distribution of *E. coli* results. Negatively skewed distribution: skewness<0; normal distribution: skewness = 0; positively skewed distribution: skewness>0.

[12] The coefficient of kurtosis measures the degree of peakedness/flatness in the distribution of *E. coli* results. Low peakedness: kurtosis<0; normal distribution: kurtosis =0; high degree of peakedness: kurtosis>0.

This is confirmed by the relative position of the 25th percentile of *E. coli* levels within class A range and shown in Figure XIII.1. The similar sizes of top and bottom box halves and relatively similar sizes of whiskers indicate similar distribution of levels of *E. coli* around the median levels. Also noteworthy is the fact that only mussels at Wells Beacon had an outlier result (asterisk) suggesting vulnerability of this bed to episodes of high faecal contamination.

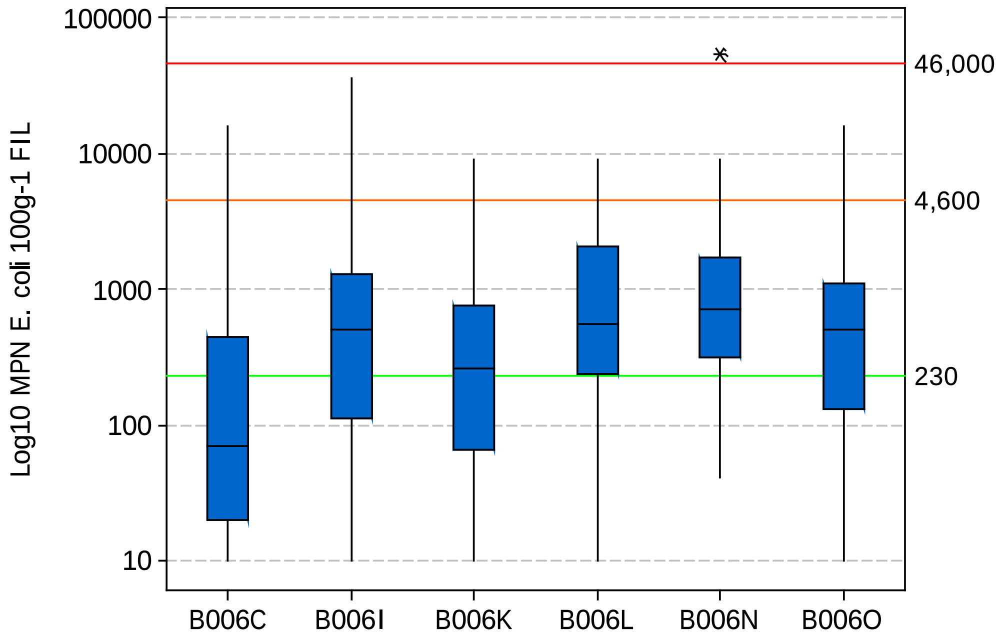

Figure XIII.1 Box-and-whisker plots of levels of E. coli in bivalves from six monitoring points in the Blakeney bivalve mollusc production area.
NB. For data periods please refer to Table XII.1.

These results appear to indicate that the representative monitoring point at Wells Beacon will be adequately representing the variation of contamination across the bed. In contrast, relocation of RMPs in inner areas of Blakeney Harbour may best represent that variation.

VARIATION OF *ESCHERICHIA COLI* ACCORDING TO RAINFALL

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally-contaminated land. The effectiveness of sewage treatments can also be reduced under high flow conditions after heavy rainfall conditions (Younger *et al.*, 2003).

Rainfall data from the Melton Constable gauging station (Figure II.1) was correlated with *E. coli* levels in bivalve molluscs from RMPs in Blakeney BMPA (Figure XII.1) for the period January 2000–May 2009.

Spearman's rho was used to estimate correlations between MPN *E. coli* $100g^{-1}$ FIL and daily and total rainfall up to seven days before sampling.

Table XII.2 shows statistically significant positive correlations between rainfall and the levels of the microbiological indicator in mussels at Simpool (B006C) and daily rainfall on the second day before sampling and cumulative rainfall between the third and fourth days before sampling.

Table XII.2 Spearman's rho coefficients between rainfall recorded at Melton Constable and MPNs of* E. coli *100g^{-1} FIL in bivalves from six monitoring points in Blakeney for the period January 2000-May 2009

		MPN *E. coli* 100g^{-1} FIL					
Rainfall		Simpool (B006C) *Mytilus* spp.	Stiffkey (B006I) *C. edule*	Morston Strand (B006K) *C. gigas*	Freshes Creek (B006L) *C. gigas*	Wells Beacon (B006N) *Mytilus* spp.	Wells Beacon (B006O) *C. edule*
Melton Constable		(n=109)	(n=93)	(n=80)	(n=36)	(n=70)	(n=54)
Daily	Day of sampling	0.061	*-0.053*	0.011	-0.069	0.008	-0.091
	-1 day	0.137	-0.011	0.094	0.106	0.139	-0.059
	-2 days	0.245*	0.029	-0.054	-0.142	-0.095	-0.103
	-3 days	0.056	0.017	-0.086	0.065	0.078	-0.044
	-4 days	-0.055	-0.054	-0.044	0.080	0.005	0.010
	-5 days	-0.184	-0.098	0.118	0.031	0.102	0.055
	-6 days	-0.012	-0.072	0.146	0.148	-0.064	0.004
	-7 days	-0.054	-0.154	0.018	-0.184	0.036	-0.085
Cumulative	-2 days	0.115	0.014	0.079	0.065	0.076	-0.090
	-3 days	0.206*	0.040	0.049	0.069	0.028	-0.039
	-4 days	0.196*	0.045	0.026	0.156	0.059	0.014
	-5 days	0.124	0.016	-0.017	0.166	0.024	-0.014
	-6 days	0.065	0.020	-0.005	0.166	0.034	0.010
	-7 days	0.050	0.036	0.031	0.218	0.042	0.028

** Significant at $p \le 0.05$.*

The relationship between variables was further explored and is graphically represented by scatterplots with superimposed Locally Weighted Scatterplot Smoothing (LOWESS) lines for statistically significant relationships (Figure XII.2). The upward trend of LOWESS line illustrates that levels of the microbiological indicator in mussels increase with increasing rainfall. However, most of the levels of *E. coli* above the class B threshold (MPN≤4,600 *E. coli* 100g^{-1} FIL) occurred when rainfall had not exceed 5mm, suggesting that other factors will be responsible for the deterioration in the microbial quality of mussels.

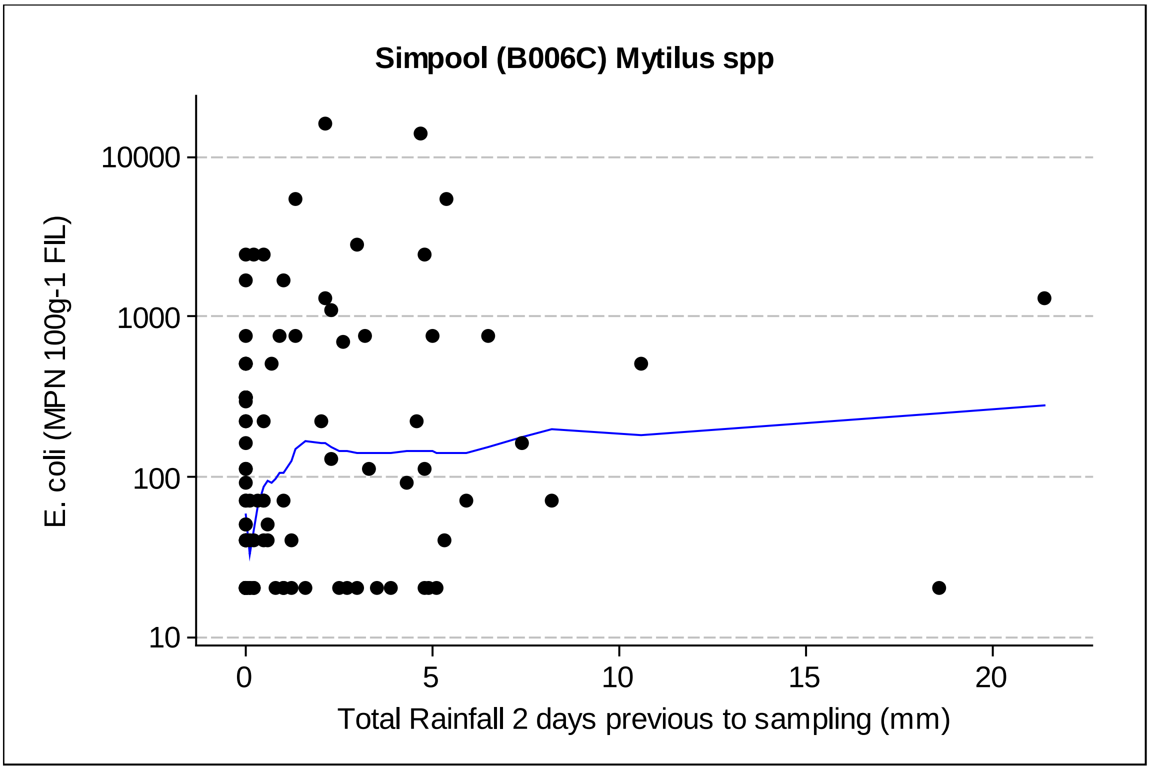

Figure XII.2 Scatterplot of levels of* E. coli *in mussels at Simpool versus total rainfall recorded at Melton Constable two days before sampling.

In the absence of significant rainfall-dependent discharges in the proximity of this bed, these results suggest that the amount of *E. coli* accumulated by mussels could be determined by contamination from the wider catchment delivered via the rivers Stiffkey and Glaven under periods of wet weather.

It is expected that sampling during/immediately after rainfall events may better reflect the worst-case scenario of microbiological contamination in mussels from Simpool, if this aspect of the *European Union Good Practice Guide for Microbiological Monitoring of Bivalve Mollusc Harvesting Areas* (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007) is adopted in the UK at some time in the future.

VARIATION OF *ESCHERICHIA COLI* ACCORDING TO RIVER FLOW

River flow data from the River Stiffkey at Little Walsingham gauge station (Figure II.1) was correlated with *E. coli* levels in bivalve molluscs from six RMPs in Blakeney for the period January 2000–May 2009.

The results from this analysis may be compared with those presented above to assess whether the positive association with rainfall found for levels of *E. coli* in mussels at Simpool will be associated with water levels in the River Stiffkey.

Spearman's *rho* was used to estimate correlations between MPN of *E. coli* 100 g^{-1} FIL in bivalves and rainfall up to seven days before sampling.

Statistically significant negative correlations were found between levels of *E. coli* in cockles from Stiffkey (B006I) and daily river flows on the third and fifth-sixth days before sampling (Table XII.3).

Table XII.3 Spearman's rho coefficients between river flow recorded at Little Walsingham and MPNs of* E. coli *100g^{-1} FIL in bivalves from six monitoring points in Blakeney for the period January 2000–May 2009.

		MPN *E. coli* 100g^{-1} FIL					
River flow		Simpool (B006C) *Mytilus* spp.	Stiffkey (B006I) *C. edule*	Morston Strand (B006K) *C. gigas*	Freshes Creek (B006L) *C. gigas*	Wells Beacon (B006N) *Mytilus* spp.	Wells Beacon (B006O) *C. edule*
Little Walsingham		(n=63)	(n=53)	(n=44)	(n=19)	(n=37)	(n=27)
Daily	Day of sampling	-0.137	-0.214	-0.107	-0.090	0.429*	0.041
	-1 day	-0.085	-0.189	-0.162	-0.186	0.241	-0.016
	-2 days	-0.056	-0.195	-0.210	-0.204	0.244	-0.062
	-3 days	-0.152	-0.271*	-0.154	-0.133	0.166	0.018
	-4 days	-0.070	-0.203	-0.001	-0.219	0.212	0.038
	-5 days	-0.162	-0.314*	0.062	-0.368	0.244	0.055
	-6 days	-0.159	-0.302*	0.141	-0.093	0.205	0.040
	-7 days	-0.130	-0.221	0.143	-0.221	0.136	0.046
Cumulative	-2 days	-0.108	-0.187	-0.155	-0.114	0.323	0.019
	-3 days	-0.084	-0.198	-0.205	-0.146	0.320	-0.002
	-4 days	-0.098	-0.243	-0.185	-0.187	0.261	-0.027
	-5 days	-0.102	-0.229	-0.159	-0.177	0.281	-0.020
	-6 days	-0.098	-0.237	-0.134	-0.197	0.285	0.003
	-7 days	-0.103	-0.247	-0.113	-0.193	0.283	0.031

** Significant at p≤0.05.*

The downward trend of LOWESS line clearly illustrates that levels of the microbiological indicator in cockles decrease with increasing rainfall and that this trend is consistent for the whole range of values (Figure XII.3). This association could be due to dilution effects at the mouth of Blakeney Harbour under high river flow conditions.

Table XII.3 also shows that levels of *E. coli* in mussels at Wells Beacon are positively associated with river flows on the day of sampling. The LOWESS line in Figure XII.4 suggests that levels of the microbial indicator increase significantly with increased water levels in the River Stiffkey, at least within the range of flows 0–0.3m^3 s^{-1}. Therefore, sampling mussels at this site when water levels in this watercourse are above the mean flow level (0.2m^3 s^{-1}) are likely to represent the worst-case scenario of contamination.

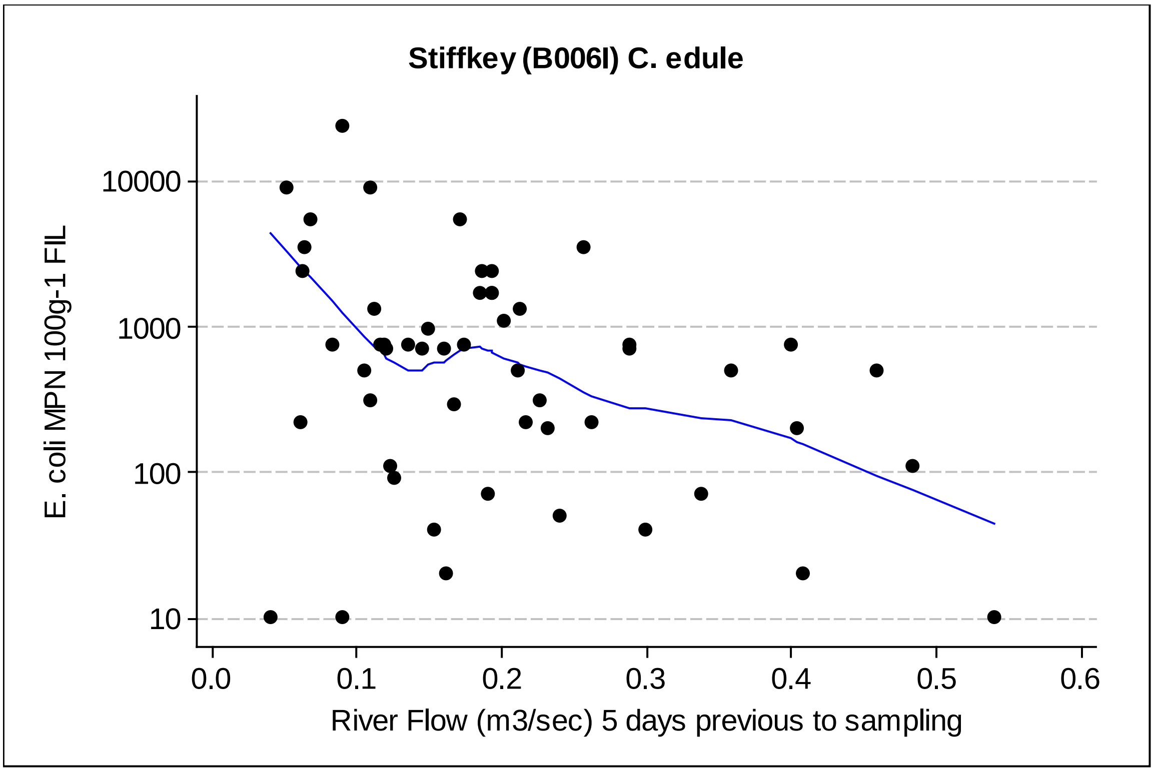

Figure XII.3 Scatterplot of levels of* E. coli *in cockles at Stiffkey versus mean river flow recorded in the River Stiffkey at Little Walshingham five days before sampling for the period Jan 2000–April 2007.

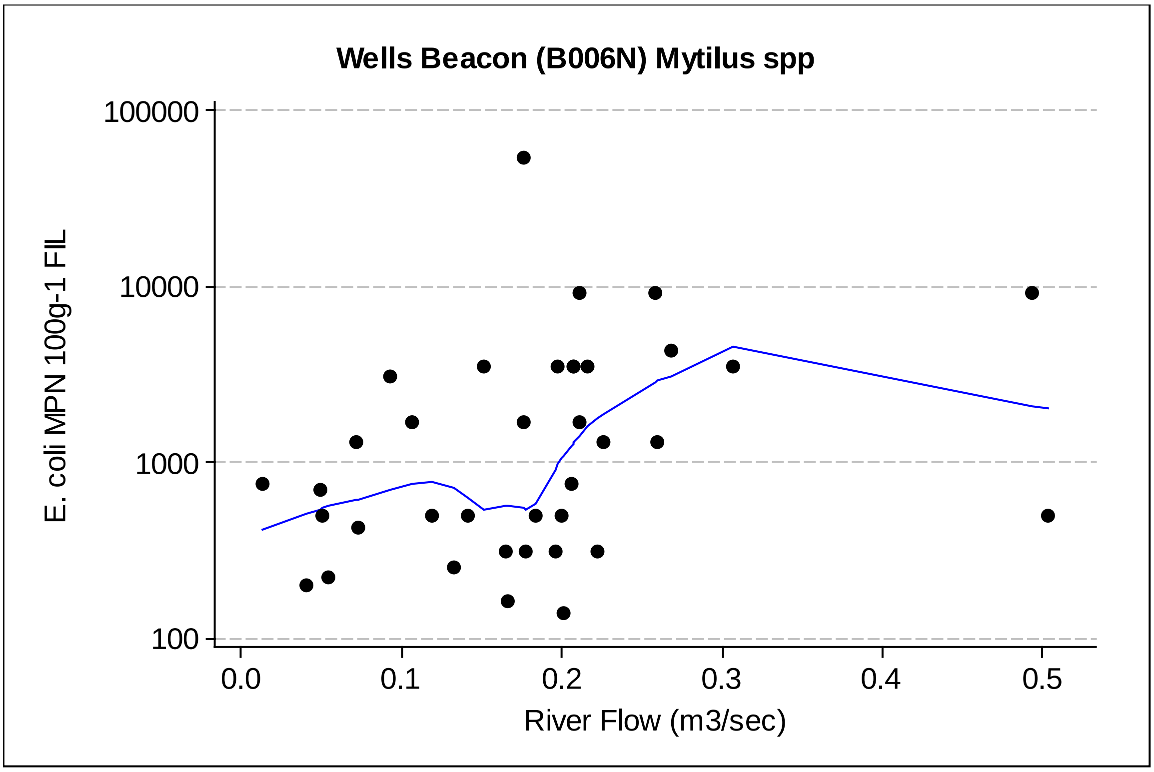

Figure XII.4 Scatterplot of levels of* E. coli *in mussels at Wells Beacon versus average river flow recorded at Little Walshingham on day of sampling for the period January 2004–Jun 2009.

SEASONAL VARIATION OF *ESCHERICHIA COLI*

The effect of season on the levels of microbiological contamination in bivalve molluscs could be due to biological activity of these animals, variation in microbiological loading due to factors such as tourism or seasonality in rainfall patterns (Younger *et al.*, 2003).

Historical levels (January 2000–July 2009) of *E. coli* in shellfish from six current and non-current beds (Simpool, Stiffkey, Morston Strand, Freshes Creek, Wells Beacon mussels and Wells Beacon cockles) was used to investigate the existence of seasonal variation of levels of *E. coli* in bivalves from Blakeney. For this purpose, data was amalgamated by season, considering spring (March–May), summer (June–August), autumn (September–November) and winter (December–February).

Figure XII.6 shows box-and-whisker plots of seasonal variation of *E. coli* levels in shellfish. In general, levels of the microbial indicator increase from spring to the autumn. However, seasonal differences are less than $1Log_{10}$ in all monitoring points.

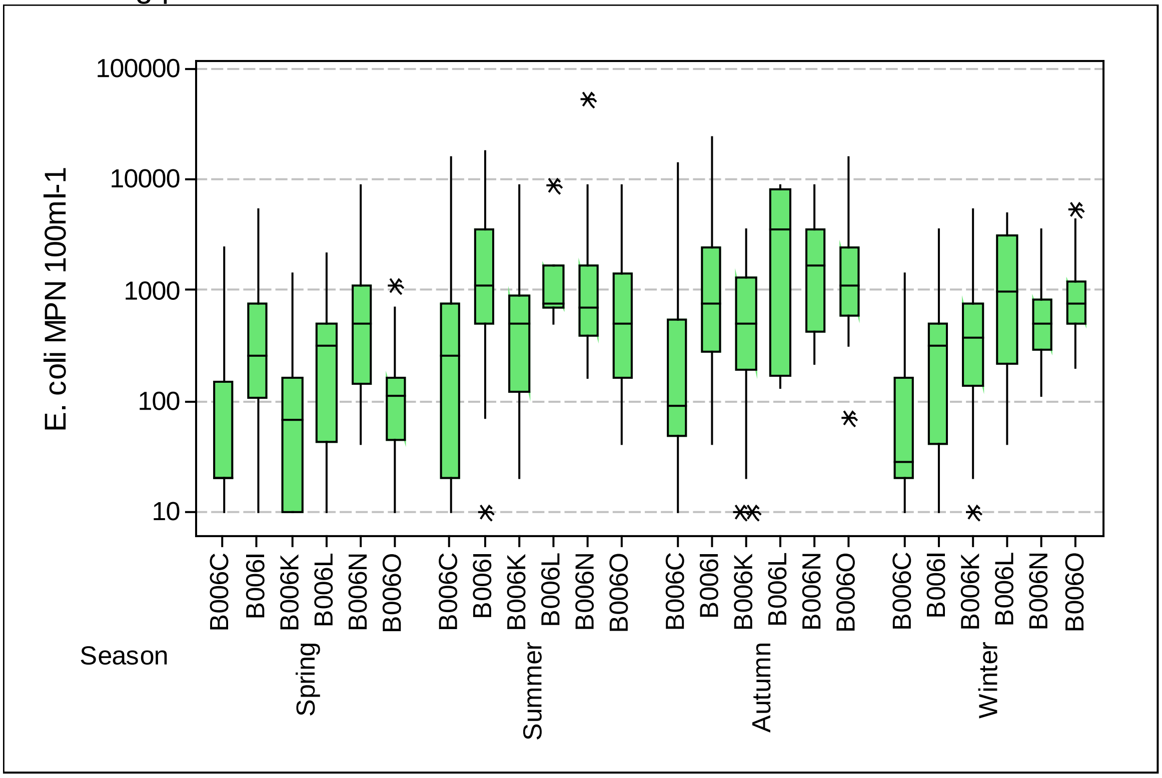

Figure XII.6 Box-and-whisker plots of seasonal variation of* E. coli *levels in bivalves from six representative monitoring points in Blakeney for the period January 2000–July 2009.

The lack of statistically significant seasonal differences in the levels of *E. coli* indicates that year-round monitoring frequency adequately reflects the variation of microbiological contamination in commercially-harvested bivalve molluscs.

APPENDIX XIII

SHORELINE SURVEY

Date (time): 7 July 2009 (08:00−17:20 BST)
Applicant: A&M Frary
Cefas Officer: Carlos Campos
Local Enforcement Authority Officer: Claire Kinsley, Robin Walpole (North Norfolk District Council).
Eastern Sea Fisheries Committee Officer: Ian Dye

Area surveyed: boat survey in Wells Harbour, followed by shoreline walks conducted in Wells-next-the-Sea, Stiffkey and Blakeney Spit Pools, including the area requiring classification for mussels at Wells Harbour and all classified beds of Blakeney bivalve mollusc production area (Figure XIII.2–3).

Objectives: (a) confirm the existence of pollution sources identified during the desk study likely to constitute sources of microbiological contamination for bivalve mollusc beds; (b) identify any additional pollution sources in the area; and (c) confirm the extent of the new bed.

The predicted times and heights of high and low waters and tidal curve on the day of the survey are given in Figure XIII.1 and Table XIII.1.

Table XIII.1 Predicted high and low water times and heights for Wells-next-the-Sea on 7 July 2009.

	Time (height)
Low Water	03:04 (0.2m)
High Water	07:21 (3.1m)
Low Water	12:59 (0.6m)
High Water	13:39 (0.6m)
Low Water	15:46 (0.3m)
High Water	19:53 (3.0m)

Predicted heights are in metres above Chart Datum.
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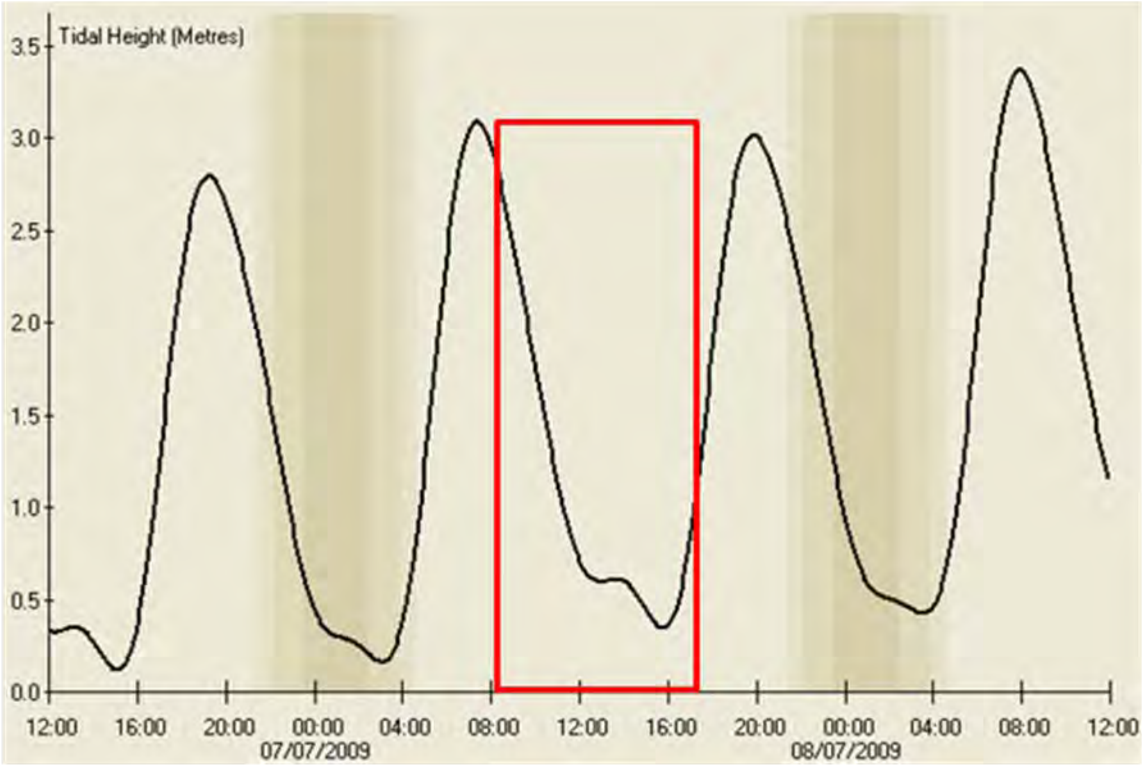

Figure XIII.1 Tidal curve at Wells-next-the-Sea on 7 July 2009.
Wells is a Secondary Harmonic port.
Predicted heights are in metres above Chart Datum Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office.
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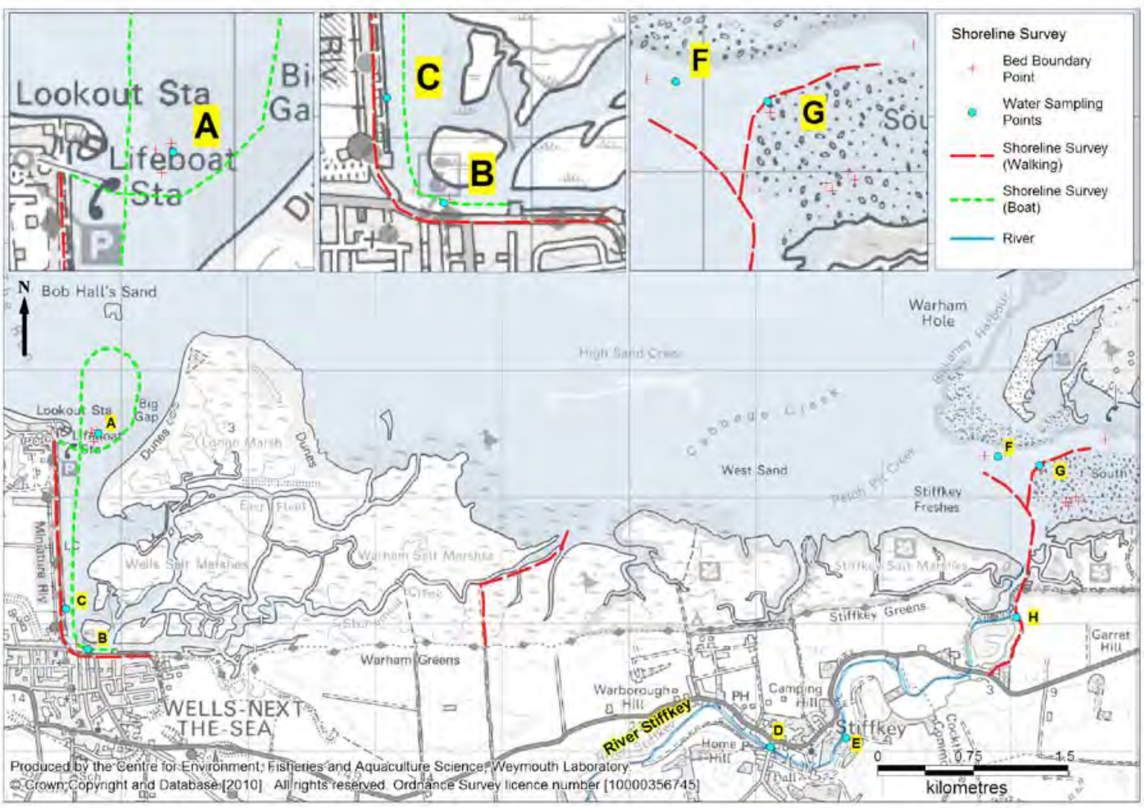

Figure XIII.2 Locations of sites surveyed and sampled in Wells Harbour and Blakeney Spit Pools on 7 July 2009.

Table XIII.2 summarises the observations made during the survey.

Table XIII.2 Observations and results made during the shoreline survey.

Classification zone and ID/species	Classification zones: Blakeney Bed name: Wells Beacon (B006O) - *C. edule*; Wells Beacon (B006N) - *Mytilus* spp.; Morston Strand (B006K) - *C. gigas*; Simpool (B006C) - *Mytilus* spp.	
Location of beds /Coordinates OSGB36 (Easting, Northing)	Wells Harbour: TF91644384 (western edge), TF91754381 (eastern edge) Mean High Water Line (southern edge)	Wells Beacon: TF91764551 (NW corner) TF91814553 (NE corner) TF91784544 (SW corner) TF91844547 (SE corner)
	Morston Strand: TF99444496 (NW corner) TF99524500 (NE corner) TF99464493 (SW corner) TF99544497 (SE corner)	Simpool: TF98804533 (NW corner) TF99754545 (NE corner) TF99244521 (S corner)
Production area	Blakeney	
Area of beds	Wells Harbour = 0.0013km^2 Wells Beacon = 0.0012km^2 Morston Strand = 0.0013km^2 Simpool = 0.041km^2	
SWD Flesh Point	TF99004530	
SWD Water Point	TF99454545	
BWD Sampling point(s)	Wells (TF91394560) Borth (260600/290100)	
Applicant's details	Andy & Martin Frary 4 Neilson Close, Wells-next-the-Sea NR23 1LU ☎ 01328 711042	
Cefas officer	Carlos Campos	
Local Enforcement Authority Officer	Claire Kinsley Environmental Health Department North Norfolk District Council, Gwynedd LL40 2YB ☎ 01263 516240	
Date/time of survey	7 July 2009 (08:00–17:20)	
Extent of survey area	Bob Hall's Sand–Simpool Head (Figures XIII.2)	
Map/Chart references	UKHO Admiralty 108: Approaches to The Wash OS Explorer 251: Norfolk Coast Central: Wells-next-the-Sea & Fakenham showing part of the Norfolk Coast Path	

Weather conditions	Wind SW turning to NW Wave direction SW turning to N
Maximum air temperature	18°C at 16:00
Wind	9knots at 10:00
Precipitation	Maximum 3.5mm at 16:00
Streams/springs	River Stiffkey (TF971143031) sampled
Significant sewage discharges (Cefas database)	Wells-next-the-Sea STW (TF9121844080) Cley-next-the-Sea STW (TG0454042470) Stiffkey STW (TF9766043030) Wells-next-the-Sea STW storm (TF9128044080) Freeman St. CSO (TF9120043820) Cley SPS (TG0460043400) Morston SPS (TG0089043680) Morston Road PS (TG0250043900)
Discharges (observed)	Wells-next-the-Sea STW (no access to outfall) Stiffkey STW High Sand Creek Caravan Park Unidentified pipe from seawall at Wells Quay (TF918643774) Unidentified pipe underneath stairs (TF919743781) (Figure XIII.3) Unidentified pipe by Shipwright's (TF919143788) (Figure XIII.4) Unidentified pipe from seawall in the vicinity of slipway (TF920243778) Unidentified pipeline discharge (possibly surface water) (TF92064378) Unidentified pipeline discharge (possibly surface water) (TF92094378) Unidentified pipeline discharge (possibly surface water) (TF92124378)
Boats/port	Approximately 450 moorings in Wells Harbour. The Harbour Master informed that although some people stay overnight, most moored boats in the harbour are day sailors. Approximately 65% of the moorings were in use at the time of the survey (Figure XIII.5)
Dogs	None observed
Other animals	Flocks of birds in the saltmarsh at Wells-next-the-Sea and Simpool Head; seals observed at distance 6 ducks in River Stiffkey at White Bridges 45 swans at Simpool Head
Strand line SRD	None observed
Samples taken	See Table XIII.2
Bivalve harvesting activity	None at the time of the survey
Sewage related debris	None
Water appearance	Seawater: clear in all beds River Stiffkey (turbid; brown colour) (Figure XIII.6)
Human population	Significant proportion of visitors/tourists in Wells-next-the-Sea
Topography	Flat land
Land Use	Urban and suburban at Wells-next-the-Sea; grassland (improved and natural) around Stiffkey caravan park

Figure XIII.3 Unidentified pipeline discharge at Wells Quay.

Figure XIII.4 Unidentified pipeline discharge at Wells Quay.

Figure XIII.5 Moored boats at Wells Harbour.

Figure XIII.6 River Stiffkey at White Bridges.

Table XIII.2 Results of samples collected during the shoreline survey on 7 July 2009.

Sample ID	Matrix	Site	Collection time	Easting	Northing	*E. coli*		Salinity (ppt)	Temperature (°C)	Water appearance
A	Seawater	Wells Harbour	08:50	91815	45504	14	CFU $100ml^{-1}$	33.7	18.3	Clear
B	Seawater	Wells Harbour	09:15	91733	43800	68	CFU $100ml^{-1}$	33.5	17.7	Clear
C	Seawater	Stream (downstream Wells STW outfall)	09:26	91560	44121	35	CFU $100ml^{-1}$	Not recorded	Not recorded	Clear
D	Freshwater	River Stiffkey	11:18	97113	43031	1,203	CFU $100ml^{-1}$	0.1	16	Turbid; brown colour
E	Freshwater	River Stiffkey (downstream Stiffkey STW outfall)	11:38	97707	43099	816	CFU $100ml^{-1}$			
F	Seawater	Simpool mussel bed (lay 1)	13:25	98904	45320	11	CFU $100ml^{-1}$	Not recorded	Not recorded	Clear
G	Seawater	Simpool mussel bed (lay 2)	13:54	99232	45249	152	CFU $100ml^{-1}$	15.4	20.3	Clear
H	Freshwater	River Stiffkey	14:54	99052	44052	345	CFU $100ml^{-1}$	Not recorded	Not recorded	Turbid; brown colour

Refer to Figure XIII.2 for locations where these samples were collected.

CONCLUSIONS

The following conclusions can be drawn from the shoreline survey:

1. The location and extent of all bivalve mollusc beds were confirmed by GPS. The areas of mussel beds at Wells Beacon and Simpool and the Pacific oyster bed at Morston Strand were noted to be considerable smaller than those held in Cefas database. It became apparent that this will limit the opportunity to change the location of monitoring points on the basis of proximity to significant pollution sources.

2. The Local Enforcement Authority informed that mussel samples representative of Simpool Head have been taken from South Side, an area outside the commercially harvested bed due to health and safety reasons. The LEA was advised to liaise with Cefas on this matter during the consultation period in case similar reasons apply to any of the recommended monitoring points following this sanitary survey.

3. The Sea Fisheries Officer confirmed that mortalities of juvenile cockles have persisted in Bob Hall's Sand since 1996. The Officer also confirmed that there wasn't harvestable stock in the sandbank and therefore the fishery is very likely to remain closed for some time in the future.

4. High number of surface water pipeline discharges was noted along the seawall at Wells-next-the-Sea Quay. Storm water runoff from the urban area is considered to represent a potentially significant risk of contamination to the new mussel bed at Wells-next-the-Sea, in particular during/immediately after periods of rainfall.

5. The close proximity of Wells-next-the-Sea STW to the mussel bed requiring classification causes concern from the hygiene point of view, in particular considering that microbiological contamination may be retained in this less flushed area of the harbour.

6. It was noted that visitors/tourists constituted a significant proportion of human population at Wells-next-the-Sea. This is likely to cause deterioration in the microbial quality of effluent sewage discharges.

7. The key feeding and roosting areas for birds identified during the desk study were confirmed during the shoreline survey. It was noted that faecal matter from these animals deposited onto sandbanks during periods of low water could impact mussel beds at Simpool during the flood stage of the tide.

8. Despite the high number of moored boats in Wells-next-the-Sea, it was noted that very few people were likely to stay onboard overnight as many were small boats without berths boats and a significant number were on drying moorings.

9. The results from water samples collected in the River Stiffkey confirmed this watercourse as a significant route of faecal contamination from the wider catchment to Blakeney Spit Pools.

10. The harvester communicated his intention to apply for classification of native oysters in the same area at Simpool in 3–4 years time.

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List of Abbreviations

AMPs	Asset Management Plans
AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CFU	Colony Forming Units
CREH	Centre for Research into Environment and Health
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
ESA	Environmentally Sensitive Area
FIL	Fluid and Intravalvular Liquid
FIO	Faecal indicator organisms
FSA	Food Standards Agency
GM	Geometric Mean
HAT	Highest Astronomical Tide
IGER	Institute of Grassland and Environmental Research
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
m OD	Metres above Ordnance Datum
MPN	Most Probable Number
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
OSGB36	Ordnance Survey Great Britain 1936
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (E. coli)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. *coli* O157 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer, goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygiene Regulations, Shellfish and Bathing Water Directives, *E. coli* is the most common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44°C as well as 37°C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and preceding the ebb tide.

Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of a skewed data such as one following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	LOcally WEighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given data set, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the *n* data points. LOWESS fit enhances the visual information on a scatterplot.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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